ELEMENTARY SCIENCE

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PREFACE.

The aim of the course in Elementary Science as outlined in this work is to introduce the student to a series of observations and experiments by which he may become acquainted with the life about him and thereby learn to appreciate the meaning of the struggles, the successes, and the failures taking place in connection with the existence of plants and animals. In other words, the course here outlined should teach the student so to use the phenomena of nature that there may be a constantly increasing and better organized body of concrete data which shall afterward furnish the basis for abstract thought, such data necessarily including materials which relate to the social and industrial environments; so to use these phenomena that a proper attitude may be formed and a greater efficiency established in solving the common problems of the every-day life. If these educational purposes are to be met in the best way, the phenomena selected for study must include those which contain a real significance to the pupils, an interest in what things are, what they are doing, how this is being done, and how all this affects the other nature phenomena and the interests of man. Such work should open new avenues of thought to the student and should tend to put him into greater sympathy with the life-forces by which he is surrounded, as well as to give him some knowledge of the principles underlying his own existence. Above all it should make him observant and should provide the means for making his life richer, more enjoyable, and hence more useful.

Little need be said regarding the method of conducting the biological portion outlined in this text. Teachers have been desiring information along the lines of Nature topics. Information has, therefore, been given a large place, but mere information, however valuable it may otherwise be, will never cause a person to be a farmer, nor incline him to appreciate a life in the country. To counteract the side of information, many suggestions are given tending to lead to independent work. The student is encouraged to find out things for himself and to go even beyond the topics of the book, should the occasion warrant him so to do. The text is both a teacher's and a learner's book. The teacher should know its contents so that due emphasis may be given the various topics at the proper time. The student, on the other hand, should accept the text as his field-book; should carry it about with him and should endeavour to see what the authors have stated may be seen. It is not necessary, neither is it desirable that one topic should be completed before a second is introduced. In other words, it is possible for the student to carry on his observations on the movements of the heavenly bodies while awaiting the development of the plant or animal life he may be studying. This is life's method of study; the teachers and the students may afterwards systematize the results.

Animal and plant biology naturally belong to the growing season and should then be studied. This does not mean, however, that the teacher and the students should forget that life exists even during the winter season.

In the months of January, February and March, Astronomy may be studied with the greatest convenience. The Astronomy given is of the simplest character, nevertheless, it is the very kind of work students and teachers are perhaps most ignorant of.

The chapters on Physical Science are intended to be made as practical as possible, in order to provide an introduction to manual training, give some knowledge of the principles underlying the occurrence of many natural phenomena, and supply such knowledge of simple mechanics as shall enable the student to understand the working of such machines as may be found on the farm, in the home, and elsewhere.

The whole course provides a good foundation for the pursuit of scientific and mechanical knowledge should the school course be continued ; in any case, it should furnish a valuable preparation for life, be this life spent on the farm, in the shop, in business, or in one of the so-called learned professions.

In order, therefore, that the best results may be secured, the authors wish to emphasize the importance of having the student make *his own* observations, perform *his own* experiments, and, in many cases make *his own* apparatus. If a saw, a hammer, a plane, and a few gimlet bits be added to the school equipment, nothing should prevent a student from making his own levers, wedges, etc.

BRANDON, *June 20th, 1908.*

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ELEMENTARY SCIENCE.

THE DANDELION.

Animals and Plants.—Nature is divided into two kingdoms, namely, the kingdom of living things and the kingdom of dead matter. Living things, the materials dealt with in *biology*, are usually classified as plants and animals, a classification readily seen when an onion and a horse are being considered, but a classification impossible to make when we come to consider the lowest forms of life. The fact is that these forms so touch and run into each other that this region has become a regular battle-ground for the botanist on the one hand claiming that a certain form is undoubtedly a plant, and the zoologist on the other, claiming just as emphatically that the same form is assuredly an animal.

When men who have made a serious study of this life-region disagree, it is needless for us to attempt to make a definition of a plant that will not include some animals, and of an animal that will exclude all plants. Let us agree with our opening sentence and think of but two kingdoms in nature, one of the living and the other of the dead. With this short account of the relation of animal and plant life to each other, we shall now consider the life-history of a plant, and the plant we shall select is the common dandelion.

The dandelion is familiar to every one. It is abundant from the time of the disappearance of the snow in the spring until the time the snow flies again in the fall.

It possesses many interesting adaptations. It is furthermore a representative of the largest family of plants growing on prairie lands. Finally, the student who really gets acquainted with the dandelion will need no one to introduce him to a study of the wheat-plant or to any other plant.

The Root.—Let us begin our study of this wayside weed by selecting a thrifty looking dandelion and attempting to pull it out of the ground by grasping the leaves. Our success or failure in this experiment will teach us that the dandelion is well anchored to the soil. Our best endeavor has only enabled us to pull up a portion of the root, the remainder is still left in the ground. To procure the whole *root-system* as it is called, we shall have to dig about the plant and lift it slowly so that few of the root-fibres may be broken. Wash off the soil adhering to the root and suspend the whole plant in a vessel of water as in Fig. 1. Such a plant will live for several weeks. What of the dandelion pulled by hand? How long will it live in water?

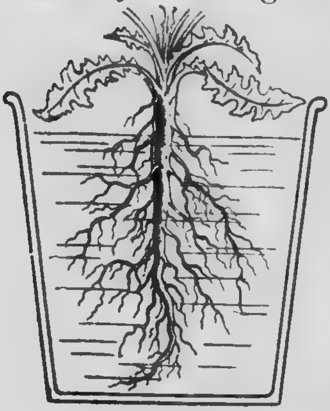
Fig. 1.

Anchorage.—The above experiment has shown one purpose of the root, namely, that of anchoring the plant. Why is this necessary? From it we have also learned how it is possible for so small a plant to resist such a pull.

We have likewise, no doubt, been a little surprised that a dandelion had so many root-branches and that some of these went so deeply into the ground. Examine the root carefully. Note the large central axis and the main branch-roots. Does it appear that the dandelion-root wishes to go deeply into the ground? Can you see the advantage of this? How is it in case of the roots of the grasses?

Looking at the plant as a whole, would it be safe to say that the dandelion has made a fairly successful attempt to possess as much of the soil as possible?

Storage.—Dig up another dandelion-root and cut the central axis across. Observe that the main root is cylindrical, that it is more or less fleshy like a beet or a carrot, and that from both of the cut surfaces a sticky, bitter, liquid oozes out. Would you say that this dandelion-milk is sap? Name other plants having the same peculiarity. What do you think it is for? The main root shows a hard central cylinder of a woody nature, and a soft pulpy ring or *cortex* surrounding this. Find out whether the main branches are outgrowths of the central cylinder or the cortex and make drawings showing the result of your examination.

All plants have not a fleshy root. Why should the dandelion? When potatoes are planted it is customary to plant a section of a potato, in other words, a *potato-slip*. When the vine has developed well an examination would reveal a black potato section, complete as to shape but wanting in substance. In fact the material of the potato section has been used in order to start the new plant. May not the fleshy root of the dandelion have somewhat the same purpose, namely, to nourish the plant at critical periods of its existence. Keeping this in view, make a note of the firm, fleshy roots of all dandelions just beginning to flower. When the flowering stage has about ended, examine the roots again. You will probably find soft and flabby roots with but little milky juice present. It seems evident that the store of ground-food put away by the dandelion has been drawn upon in this particular instance by the plant in its work of seed-making. Seed-making, if you will observe, seems to be a severe strain upon all plants. But this is not all. Can you explain why dandelions look so fresh and green when most other plants have withered or are withering from want of rain? May not the same storehouse help to tide the dandelion over such a time? People, at least a few people, believe in putting some of their earnings in the savings bank. We commend such for their forethought. Why not be as generous to the dandelion? Has not this plant been toiling away in the good weather and laying by extra provisions for a time of scarcity? May we not also say that the dandelion uses its root as a sort of underground storehouse where food may be kept out of the reach of animal enemies?

Soil Food.—Look again at the plant left in the water. Can you find out the total length of its roots? How does the root system compare with the part above the ground? Would it be safe to say of a wheat plant, for example, that its root system is as large as its leaf system? Following the branch-roots to their ends, notice how delicate the small end-roots are. Let us try to find out what this means. Pull up a dandelion and let the plant lie on the ground for a few hours. The plant withers. The root must be getting something from the ground to prevent this. Has the dandelion first placed in the water withered? Why are house plants frequently watered? Why do farmers wish the rain to come after the fields have been sown? Why do farmers wish occasional rains during the growing season? Gather a handful or two of green grass and weigh it. Leave the grass in the hot sun for a few hours and then weigh it again. What have you found? What is the explanation? Do all these experiences justify us in making a statement to the effect that *roots are organs by means of which water is taken into the plant?* It would seem so since plants look greener and fresher in wet than in dry seasons and roots appear to make for that part of the ground where the moister soil lies.

Osmosis and Capillarity.—How does the water get into the plant? This is a difficult question to answer, but you may easily understand the main features of the process. Obtain two plates of window glass four by five inches. On one place half a dozen sheets of blotting paper cut a little smaller than the size of the glass. Cut four strips of wood so as to fit the glass just outside the paper. Moisten the blotting paper well, and scatter over it some well soaked seeds of wheat or any other small seeds. Cover the box with the other glass side and the germination-bed is complete.

In a few days, if the conditions of germination are good, you will observe a great many fuzzy looking hairs on the root of each germinating seed. These are the *root-hairs*, and it is here we must first look for the method by which water enters the plant. These hairs are merely bags of a living liquid called *protoplasm:* the wall of the bag and the liquid forming what is known as the *plant-cell.* Through the very thin wall the water enters by a process called *osmosis.* The result of this process may readily be seen by taking a fresh egg and preparing it as follows:—Break the shell at one end, and pick it bit by bit from the delicate membrane lying beneath it. Now break a small hole in the shell of the opposite end of the egg just large enough to admit a small glass tube. Cement the tube in with sealing wax or paraffin, and place the egg and tube in a small glass of water as in Fig. 2. Pierce the egg-membrane at the bottom of the glass tube by inserting a hat pin. In a few minutes the contents of the egg will be seen to rise in the tube, and the water in the tumbler will lower a little and may change very slightly in color. In some mysterious manner the water has entered the egg and some of the egg has entered the water. There has been an exchange of liquids but not an even exchange, for the tube will show that more has entered than has left the egg. What has happened is simply this: we have separated a dense liquid, the egg-material from a less dense liquid, the water by a porous animal membrane, the inner lining of the egg, and the result observed has followed. Applying what we have seen to the plant-cell we have the very same conditions: a denser protoplasm in the cell, and water containing a very small amount of mineral material in the soil. These are separated by

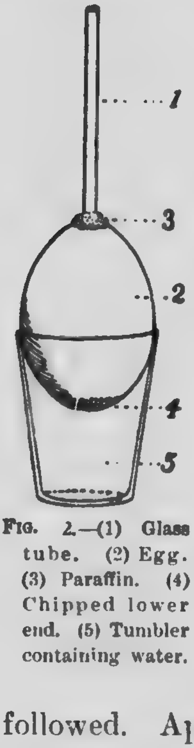

FIG. 2.—(1) Glass tube. (2) Egg. (3) Paraffin. (4) Chipped lower end. (5) Tumbler containing water.

a vegetable membrane, namely, the wall of the cell. More liquid enters than leaves the cell, the result being that the cell wall is stretched to accommodate the extra water that has entered. As this cell is alongside of the cell within, the cell *a* of Fig. 3, we have again a denser liquid, the liquid of *a* separated from a less dense liquid, that of *b* by a porous wall or double wall. The result is a second exchange, and so the water with its mineral matter or dissolved salts moves slowly inward until it reaches the many long tubes of which plants are largely composed, and which may be seen by cutting across any piece of wood and examining the cut ends for the openings of these tubes. The water mounts these tubes by another process, that of *capillarity.*

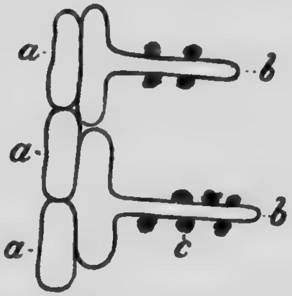

FIG. 3.—(*a*) Inner plant-cells. (*b*) Root-hairs. (*c*) Soil-particle.

Before explaining the process of capillarity we should say something about the intimate contact of the root-hairs and the soil particles. You will find if you examine the grains of wheat which you have sprouted in your germination-box that the root-hairs have bound the little plants to the blotting paper. How have they done this? In the same way these hairs are in contact with the smallest soil particles, and the water of greatest value to the plant seems to be the film of water surrounding these particles.

We have mentioned that plants have tubes, and that the soil water or crude sap rises in these tubes by capillarity. Coal oil rises in the lampwick because the lampwick is composed of tubes. If the end of a towel dip into the water of a basin, some of the water will rise in the towel. If a glass tube be held in a flame until the glass softens, a long fine tube may be drawn out. If the end of such a tube be placed in ink the ink will rise much higher in the tube than in the ink bottle. All these are but instances of what we called capillarity, so that we may say that water rises in a plant partly by this process. To see just where this takes place dip a twig of maple into a bottle of red ink and leave it for a few hours. If the end of the twig be cut under water and quickly placed in the ink, air will be prevented from getting into the tubes and thus interfering with the rise of the ink. Beginning at the end, cut off section after section and show by means of a diagram the region through which the ink rises.

By these two processes, that is, by osmosis and capillarity, liquids enter and rise through plants. But osmosis and capillarity are not all the processes controlling the water supply of plants. These will, however, help the student to appreciate the complexity of such an apparently simple thing as a common dandelion. The root of the dandelion has therefore three important functions, namely, to anchor the plant in the ground; to serve as a storehouse of the surplus food and to gather water and mineral salts from the soil. In connection with the last of these, you may easily understand why farmers have to add fertilizers to the soil and why it is possible to let soil run out and become barren.

Root-cap.—There is still another feature in connection with the roots of the dandelion, and of roots in general that we should recognize. Roots have to force their way through the soil. Such work must be wearing on the root-ends. To guard against this each root-end is provided with a sort of thimble or *root-cap,* which is continually renewed behind so that it never wears out. This cap may be seen with an ordinary magnifying glass at the end of the roots of the specimens in your germination-box. It appears as a denser part just a little back of the root-tip. Fig. 4, *a*.

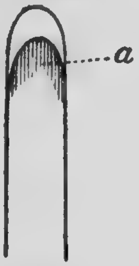

FIG. 4.

Your examination of the root-system will also likely reveal the fact that some of the root-fibres have been bent. They show signs of having met some obstacle they could not penetrate. You have seen the ends of twining plants reaching out for something to cling to. Why should not root-ends do the very same thing if by so doing they can get around any sticks or stones found in their way?

As water is so important to the well-being of plants and as the soil is the usual medium supplying this water it is well to know at this point whether the various soils of the locality are equally valuable in the matter of retaining moisture. To help you to decide this for yourself put equal weights of dried leaf mold, sand, clay, gravel, loam, etc., into separate sealers. Add to each the same weight of water, and allow sufficient time for the soil to become saturated. Invert the jars as in

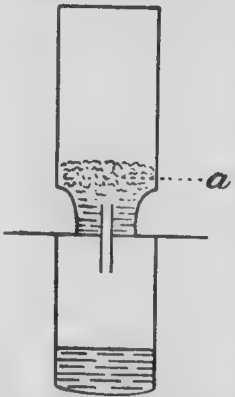

FIG. 5. — What kind of soil retains water best? *a* = soil.

Fig. 5. The water retained constitutes the water supply that plants could depend upon from such soil. What have you found this to be?

Leaves.—If the root of the dandelion has so many interesting features the *rosette* of leaves must also have a few. Select some particular dandelion and keep it stripped of its leaves. If this be carried on long enough, the plant may be destroyed. Surely the leaves of a plant must then have something to do with the plant's well being? What this is we shall learn later. At present we shall select a dandelion with a great mass of leaves. Lifting these we shall find that the ground beneath the plant is bare; that it is likely wet and that there are quite a few dead and rotting leaves beneath the rosette. What is the explanation of these three facts? The first is readily answered. The big leaves have smothered out the grass. The same result would have followed the placing of a board on the grass, and the presence of high weeds in a wheat field may result in a similar smothering of the wheat plants growing in the shade of the weeds.

Light Relations.—Stand so that the eye may take in the whole dandelion rosette. Count the leaves when in this position. Count the leaves again one by one, compare the two results and account for the reason why the dandelion seems so careful in placing its leaves. Find if other plants exercise the same care. Why do plants as a rule face the sun? Look about and see if a dandelion cannot be found trying to get from behind some obstruction so that it may be placed in better relations with the sun. May we not make the statement that plants place their leaves so as to get the full benefit of the sun and perhaps of the air? Does the rosette habit of the dandelion seem to meet all the needs of these two relations?

Capillarity of the Soil.—We also found that the ground beneath the rosette of the dandelion was quite moist. What is the explanation of this? Place a board on the dry ground and lift it in a few days. The ground beneath the board is no longer dry. What is soil but a mass of very fine particles of clay, sand, etc. These particles make a host of very irregular capillary tubes up which the lower ground water is rising. Without the board or leaf coverings this water would evaporate just as rapidly as it reached the surface of the ground. The dandelion may, therefore, be said to conserve the ground water for its own use, surely no small matter to a plant.

Self-pruning.—The dead leaves already observed are not simply the leaves of last year. There may be some of these present, but the remaining leaves have probably been of service to the dandelion not later than a few weeks before. Would you expect these leaves to be the oldest or the youngest leaves of the plant? Which would you expect to be of the greatest service to the plant, the fresh, young leaves, or the old ones, stiff with age and likely filled up with material that came up in the sap but was of no use to the plant? Which should be of greater service, the young leaves, free from dust or the older leaves all dust-laden and probably battered by the feet of cows and horses. Do you see why the dandelion should, after a time, shade these leaves and lop them off? This is the way plants prune away worthless limbs and leaves. Can you see how the dead leaves may afterwards be of some value to the soil, and consequently to the vegetation growing in that soil?

Leaf-mechanism.—Now examine a dandelion leaf. If all leaves grow on a stem, what kind of stem has a dandelion? Show in what particulars such a stem may be a good thing for this plant. Note among these the way dandelions can dodge the lawn mower, and also how they may escape being eaten by herbage-loving animals. The leaf is a thin, expanded, green organ connected by a sort of stalk to the stem of the plant. The expanded part is called the *blade*, and the blade is divided by a heavy centre line, the *mid-rib*, into a right and a left part. The stalk is called the *petiole* and the blade and petiole usually constitute the leaf. From the mid-rib you will see many side branches extending almost to the leaf edge. These are the larger leaf *veins*. Hold the leaf up to the light and observe how the veins divide and subdivide until a perfect network is formed. What is one purpose of the veins of a leaf? Has the form of the leaf anything to do with the arrangement of the main veins? Look at the peculiar lobes at the margin. Can you point out the advantage of having such lobes? Do they help the plant in the matter of securing better light? May they not be helpful to dandelions growing in long grass? Notice the upper and lower surfaces of the mid-rib. Can you see any reasons for the hollow in the upper surface and the projection in the lower? Observe that the leaves of the dandelion are so placed that they form a system of water-troughs or gutters for collecting the dew and the rain and directing these to the main root. Point out some of the advantages of this arrangement.

Cut the petiole across near the end and examine the cut surface. You will notice, perhaps, three features; you will see that the milky liquid observed in the root is also present here, that the stalk is hollow and that the form of the stalk is somewhat curved. Suck the end of the stalk in order to clear away the milky liquid. Do not be afraid that this will poison you; remember that the dandelion has long been of service as a medicinal plant of remarkable excellence. Look again at the cut surface with a magnifying glass. You will see something like the ends of green rods so arranged as to form the curved shape already noticed in the stalk and the midrib. Procure a plantain or bird-seed plant and pull off one of the large leaves. The plantain rods are easily pulled out. They are woody in character and are filled with tubes through which the crude sap or water from the root reaches the leaves. Allow a few cut dandelion leaves, or other leaves, to stand in a little red ink. In a few hours the ink may be seen in the veins of the leaf.

The hollow noticed suggests an air-space and furthermore hints that air may be as necessary to plants as it is to animals. We may wish to learn to what extent air is found in the body of a plant. We shall, therefore, immerse a fresh dandelion leaf in hot water and observe the number of air bubbles that appear on both the upper and lower leaf-surfaces. Are there more of these on the upper than on the lower surface? Do you know why the heated water caused the air bubbles to appear? Do you think a hot day would have the same effect? Do you think we are justified in concluding that air must be needed by plants for if not how are we to account for its abundance in the very material of the leaves? Tear a leaf across and examine the torn edge. You will find a very delicate skin or outer layer which must be for the protection of the soft, spongy, green looking material within the leaf proper. Were a portion of this delicate skin placed under the large microscope it would look something like Fig. 6. The leaf-surface is pierced by numerous peculiar pores or mouths, to which the name *stomata* has been given. Each *stoma* or mouth shows two crescent shaped cells in contact at the ends and leaving between them the opening referred to. There are more of these mouths on the lower than on the upper side of the leaf, because the latter surface, being exposed to the weather, must have its epidermis thickened and toughened so much that flexibility would be wanting in the opening and closing of the stomata. Again, the upper surface is more likely to become more dust laden than the lower surface. How would this interfere with the stomata?

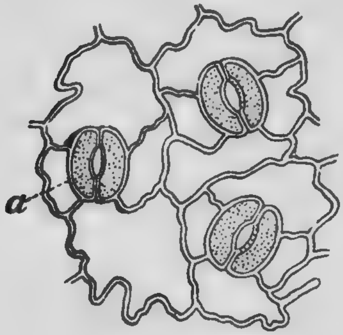

FIG. 6.

Starch-making.—What is done with the air taken in by the leaves? Air contains an important plant food, carbon dioxide. To get this, leaves must be placed so as to command the air as well as the sun. A leaf is really a small factory where the carbon dioxide of the air, the mineral matter of the ground, and a portion of the water conveyed by the roots, are united chemically into a substance called *starch*. Plants and plants alone seem able to make starch. Starch is made only during the sunlight and this is one reason why plants are so careful in placing their leaves where they can get the full benefit of the light of the sun. Plants, however, require something else to help in the starch-making process. This something else is the green coloring matter of the leaf, namely, *chlorophyll*, that is, green-leaf. Place a board over green grass and you will bleach the grass. Remove the board and the chlorophyll will soon show itself. Boil a dandelion leaf for a few minutes to soften its substance, then place it in a small quantity of methylated spirits or alcohol. The green coloring matter will color the alcohol and the leaf will be bleached. The starch-making process is a very complex process, but the facts are given as above.

Plants and Oxygen.—Besides having to make starch, plants also are oxygen makers, oxygen being given out by the stomata in the day time, so that plants take one gas from the air, a gas we give off in breathing, and return another gas, a gas we require to purify our blood and keep our bodies in a healthful condition. But how do we know that oxygen is given out by plants and carbon dioxide taken in? Have you ever examined the green scum often seen on the surface of stagnant waters in the summer time? Should you stir this scum you will notice a great many bubbles of gas adhering to it and helping to float it. Get a test tube of this gas and test it for oxygen. Your teacher will help you to do both these problems.

Another experiment easily made consists of taking a few fresh green leaves, placing them under water, and exposing the whole to the sunlight. Bubbles of oxygen soon appear on the leaf edges. To prove that the sunlight is essential in this oxygen-making process, cover the vessel with a piece of black cloth, or shade it in some manner, when it will be found that the bubbles of gas will cease to form. To carry out this experiment more fully, place the funnel *a*, Fig. 7, over a mint plant anchored in a suitable vessel of water. Over the funnel place a test tube, *b*, full of water. Place the whole in the bright sunlight and test the gas collected for oxygen.

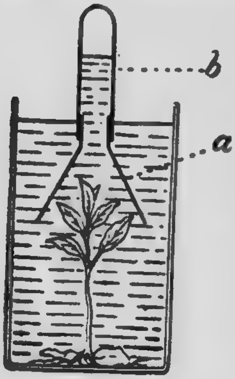

Fig. 7.

If plants are oxygen-makers would you consider the placing of parks in large cities as conducive to the health of the city?

Plants and Carbon dioxide.—Plants are also carbon dioxide users. Place a splinter of wood in a test tube and heat the tube. The splinter blackens, showing the presence of charcoal. Charcoal is carbon, and carbon is a constituent of the gas carbon dioxide. Where did the plant get this carbon? We may answer this in several ways. Purchase, or prepare some plant food. Add a small quantity, say a half teaspoonful, of this to a quart of soft water, or better, to distilled water, and grow a dandelion in the liquid. Plant food does not contain any carbon, and yet the dandelion stores up carbon, a fact that may readily be proved in a similar way to the experiment with the bit of wood. There is no place to look for this carbon but the air. Again, place a mint plant in a bottle as in Fig. 8. Force air that has been kept for a considerable time in the lungs into the bottle, and set the whole in the sunlight from morning to evening. A bottle filled with such expired air as we have described will not support the combustion of a splinter of wood quite as well as ordinary air, and the air of the bottle in which the plant was placed will, in the evening, show signs of being much richer in oxygen than it was in the morning, a proof that the plant has taken away some of the carbon dioxide which is always present in expired air, and has replaced it by oxygen. If this test with the flame had been delayed until the next morning would the same result follow?

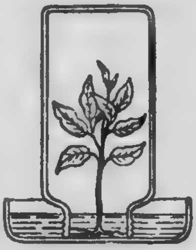
FIG. 8.

Starch and Sugar.—All day long during the growing season our dandelion is busily engaged making starch and either using it to build itself up, or else storing it underground, away from the reach of any animals that might use it. Starch, however, is not a soluble substance like sugar or salt. How can the dandelion, or any other plant get this starch away from the place where it is formed? A potato is largely starch, but have you taken notice that when you put a bit of cooked potato in your mouth it tastes sweet. Your physiology accounts for this by pointing to ferments in the saliva. Why should not plants have ferments just as well? They have, and here the explanation of the removal of the starch comes in. During the night the starch is acted upon by certain plant ferments and changed to sugar, a soluble substance. The sugar is then removed from the region of the leaf and taken to any place in the plant where building and repairing are going on, or else to the root, as in the case of the dandelion, to be stored up for any emergency.

Respiration.—The dandelion also needs oxygen for the protoplasm. The dandelion therefore breathes as we do, namely, by taking in air whose oxygen in turn combines with the carbon waste of the body and is removed as carbon dioxide. There is a difference however: the dandelion is a carbon dioxide user; the dandelion removes its own smoke, as it were, so long as the starch-making process is going on. As this process takes place during the sunlight hours, the presence of this gas may not be observed. At night, when the starch ceases to be made, the dandelion breathes just like a human being in so far as the inspiration of oxygen and the expiration of carbon dioxide are concerned. How do we know that plants sometimes give out carbon dioxide? Cover a plant in the evening with a close-fitting jar, a bell-jar is a good thing. Vaseline the jar where it rests on the table. All night long the plant is breathing like an animal. In the early morning a splinter-flame will reveal the presence of an excess of carbon dioxide. If this is the case what have you to say regarding the placing of plants in a sleeping room? How is it in the case of sleeping in the forest?

Transpiration.—There is still another feature in connection with the leaf that should be mentioned. Plants take in a great deal of water by means of their roots. The immense root-system of the dandelion is simply the means by which an abundance of this ground-water is secured for the plant. In this water certain mineral salts, some of which are of use to the plant, and some of no use, are dissolved. These ultimately reach the leaves where the valuable mineral salts are changed to proper plant food and used by the plant. It will be readily seen therefore, that much more water reaches the leaves than is needed by the plant for the purposes of growth. Something must be done with the excess. Leaves, besides attending to the many wonderful activities already referred to have also to look after the work of removing the surplus water absorbed by the root and transmitted to the leaves. The process by means of which this is effected is called *transpiration*, a process somewhat similar to the human process of perspiration. How and where does transpiration take place? Where should it take place but in the leaves. Look at the immense area of the leaves of even so lowly a plant as the dandelion. How many square yards of leaf-surface do you suppose the wheat plants on a single acre cover? Of what value is so great an area to the process of transpiration? Look again at the thin leaves. How may this aid? Finally, think of the thousands and thousands of stomata on a single leaf-surface, and the channels connecting these mouths with the interior of the leaf. Could there be any more perfect mechanism for the removal of the water? It is indeed so admirable that plants have to guard against too great a loss of water, and in this some plants fare better than others. Have you ever seen leaves droop on a hot summer day? Do you know the cause of this? Do you know why such leaves lift up again in the evening? Could you see the *guard* cells as they are called of the stomata, in other words, the crescent-shaped cells, Fig. 6 (*a*), you would see these cells come closer in order to make the openings smaller. What should follow this movement? Were the ground sufficiently moist during such weather do you think the leaves would droop so easily? Why? Have you any idea of the amount of water it takes to supply a wheat field of ten acres during the growing season of the wheat? It has been estimated that an oak tree in full leaf may evaporate *two hundred and twenty-six* times its own weight of water in the growing season. If this appears in any way extravagant, you may easily prove it for yourselves.

Fill two or more bottles with water, and cover them tightly with sheet rubber to prevent evaporation. Mark the height of the water in each bottle and insert through a hole in each rubber sheet a sprig of any plant you wish to experiment with. Place the bottles in the sunlight and note the quantity of water that disappears in the course of twenty-four hours. Now ascertain as well as you can the total leaf surface and the weight of water lost. Make an estimate of the total number of leaves on the plant from which the twigs have been taken. What weight of water has the plant lost in the day? Should the twigs lose more or less if left upon the parent plants? Try the same experiment once during each of the months of the growing season. From the average loss ascertain the amount of water lost during the season. From this account you will see that every plant: wheat, weed or tree is simply a pump, drawing up water from the ground and giving it again to the air. As evaporation is always a cooling process this enormous evaporation must be the means of keeping the temperature of the plants much lower than they otherwise would be. Another experiment illustrating the loss of water by leaves should be made. Place several leaves in water as in Fig. 9, first sticking the stalk-parts through the hole in the cardboard (*a*). Cover the leaves with a tumbler and set the whole apparatus in the sunlight. After a time observe the bedewed inner surface of the upper tumbler and account for it. If plants require so much water, there is no wonder that farmers are so anxious that seasonable rains should occur during the growing season, and that an attempt should be made to obtain two season's rainfall for a field of wheat. Do you know how this is effected?

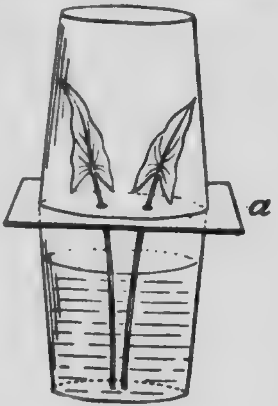

FIG. 9.

We have now found that the leaves of the dandelion are organs by means of which starch is made, the excess of water removed and breathing effected. We have also learned that the leaves of the dandelion are so arranged as to get the full benefit of the sunlight and the air. We have likewise seen how the leaves are made to serve the purpose of water troughs for the rain and the dew. The dandelion rosette furthermore covers the ground, thus conserving the ground water and smothering the leaves and eventually killing such plants as may come into competition with it. We have seen, in a word, the selfish side of the dandelion, or the dandelion working by means of root and leaf for its own well being. We shall now consider this plant in the work of reproduction, that is, as producing and providing for its numerous offspring, the seeds.

The Flower.—After the dandelion has secured a firm grip of the soil, has developed a goodly sized rosette of leaves and has stored up a bountiful supply of plant food in its thick *tap* root, evidences of flower-formation may now be seen at any time. The first sign of the flower is seen in the appearance of a few tiny, green flower buds, carefully guarded at the centre of the rosette by the youngest leaves of the dandelion. In a few days these buds will have so increased in size that an examination of them may easily be made. Opening the green leaves of the bud, the centre discloses the yellow so well known in the dandelion blossom. The purpose of the three circles of green leaves is very evident. What is this purpose? In a couple of days the blossom will have opened of its own accord and the outer two circles of green leaves will have curled back, to take part no more in the work of protecting the flower. Dandelions are cautious plants, however, and in the early spring and the late fall the flowers seldom are seen perched in the cold air, but remain close to the warmer ground, a feature in dandelion life worth seeing. What are the green leaves surrounding the flower? Where do they differ from the big leaves already referred to? These reduced leaves are called *bracts.* If you examine a number of flower-stalks you will be sure to come across cases where these leaves are not all in their right places. You will find some straggling down the stem. Note the form of the lowest of these. Do they suggest the big leaves on the ground? May this mean that the dandelion was not always as we see it to-day?

The Involucre.—These bracts constitute what is called the *involucre* of the flower; in other words, a circle, or several circles of green leaves surrounding a flower for the purpose of protecting it. The bracts overlap, if you will notice, like the shingles on the roof of a house. What is the advantage of this? Two circles of the involucre curl up at the opening of the flower; the third or inner circle of bright green bracts still remains on duty. After the flower has been open for a couple of days it closes up. Dandelion blossoms may close during a rain shower, or at night. Do you know why? When the flower closes the little green leaves mentioned close in and make a capital green tent. Many people have seen and have admired this greenhouse, but few have ever taken the trouble to look in in order to see what was going on. Should you see the dandelion in this condition watch it closely, for something wonderful is going on. In a few days it will open again; the faithful green circle will roll back and the beautiful dandelion ball will unfold itself. But what was happening in the little green tent? To answer this we must go back and make a closer examination of the dandelion flower and flower-stalk.

The Flower-Stalk.—Every one knows the flower-stalk of the dandelion. Who has not made whistles of it? Who has not cut it up for the sake of seeing the ringlets? Why is it hollow? Why does it lengthen so fast after the flower opens? What makes the ringlets? How many questions we have to ask about this very interesting thing! Does not the hollow stalk hold up the flower perfectly? Why should the dandelion waste valuable material, then, in filling up the hollow? Why have builders made so much use of hollow iron cylinders for the support of buildings, do you think? Why do plants so often fill the centres of branches and stalks with pith, a substance that can be of very little account as a means of support? Roll up a sheet of paper into a cylinder, and ascertain the weight it will support. You may now see some reason why nature has made the hollow flower-stalk of the dandelion. But why do dandelion and rhubarb stalks curl? Put the curls of fresh dandelions in very salty water and see what happens. Think of what was said regarding osmosis and try to explain the result. The fact is the stalk of the dandelion in its pulpy parts is gorged with water. This is why it is so stiff. Why should the stalk lengthen? What is at the end of the stalk? Do you think the dandelion wishes to be seen? Watch the numbers of insects that are working through the yellow part of the flower. How do you suppose they knew that this flower was ready for them? May not the height of the flower and also its bright color have aided?

The Head and its Parts.—Coming to the flower, we shall find, not just a single flower like the flower of the rose, but a great many flowers, very small to be sure, but appearing all right in the mass. One single flower, or *floret* as it is called, would be passed by as too insignificant; but a mass of these florets is very conspicuous, and the children think the dandelion lovely! Does the dandelion gain anything by this massing of its little flowers? This remains to be seen, but we can venture the thought here that each floret must have gained in actual worth what it has lost in size and showy ornamentation. Selecting one floret then, try to make out the following features, by referring to Fig. 10 and then to the floret for identification. Look at the yellow strap-shaped leaf (*a*). Notice near its base that it is a tube split down one side. Count the points, or *teeth*, at the end. Each suggest a leaf, so that this yellow leaf is really made up of five leaves united. Look for the seams showing this union. This organ of the flower is largely for the purpose of advertising the flower. It is called the *corolla*, and the separate leaves composing it are the *petals*. The union of the petals is described in botany as *gamopetalous*. Now examine the silky h[illegible]t (*b*). At their base these unite to form the short tube or neck you see on the floret. Look at the outer covering of what you have no doubt called the seed, and you will see lines going from the point of the seed to the top of it. Counting the heavier of these lines you will discover that there are five, and probably five other much less distinct lines. If we put all these points together we shall have some reason for concluding that the covering of the seed is really made up of five leaves, the heavier lines representing the edges where adjacent leaves have joined, and the fainter lines showing what is left of the mid-ribs. These five leaves cover and protect the seed and form the short tube at the top. The silky hairs are the frayed teeth of these

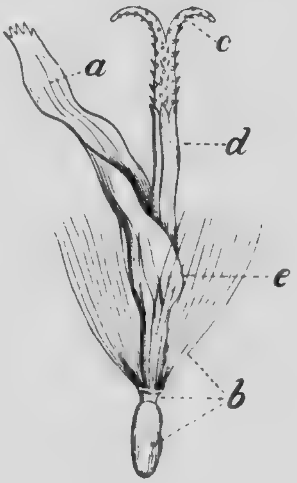

Fig. 10.

leaves modified for the purpose of helping to carry the seed away from the plant after the seed has ripened. In the rose this circle of leaves or floral organ gets the name of *calyx*, and the separate or distinct leaves forming the calyx get the name *sepals*. The union of the sepals is described as *gamosepalous*. Examining the part marked (*c*) you will find two yellowish white curls united to form a tube. Follow this tube down through the thickened part marked (*d*). It may be traced all the way to the seed. In fact this part looks, if isolated, like Fig. 11. Cut the stalk of this part just at the opening of the corolla tube and pull it through the mass *d*. It is found to be quite distinct. This part or organ is called the *pistil*. The two horns at the top make up the *stigma*, *a* (Fig. 11); the stalk (*b*) is the *style* and the part (*c*) inside the calyx covering is the *ovary*. These three constitute the pistil, or female portion of the flower. The remaining part of the flower, the part marked (*d*) is the male organ, or *stamens*. The stamens are made up of two parts, the heavy part (*d*) and the very fine thread-like stalks (*e*) going back and growing upon the inner wall of the corolla tube. The bag-like heads constitute the *anthers*, and the stalks are the *filaments*. The anthers are united in a ring about the style, so are supported by it, and hence the very delicate thread-like stalks forming the filaments. All that is required of the filaments is a means of bearing food material to the anthers.

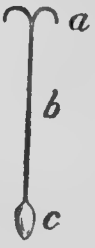

Fig. 11.

Function of Parts.—What a wonderfully complicated thing a dandelion floret is! What is the meaning of all these parts? We have pointed out already that the calyx protects the ovary and furnishes the means of flight to the seed. The corolla is for advertising purposes simply, while the stamens and the pistil are for the purpose of bringing the seed into existence. Let us look at each of the latter organs for a while. The stamens, we have said, are made up of anthers and filaments; the filaments we have explained. The anther is really a double sac, which when mature is filled with a living dust called *pollen*. Shake a fresh dandelion blossom over a darkened surface, or stick the flower to the point of the nose; in both instances pollen dust is seen, though a looking glass will be necessary in the second case to make this dust visible.

Fertilization.—Pollen dust, or pollen grains rather, are usually spherical in shape, and contain a living liquid bearing what may be termed the male life-germ. Each of these little specks of life is surrounded by two coats. Should a solution of three grains of loaf sugar and twenty cubic centimetres of soft water be made, and a drop of this placed in the hollow of the glass accompanying a compound microscope; should pollen from a fresh dandelion flower further be shaken into this drop and the thin glass cover placed on the slide, the student would see a strange growth or development of each pollen grain in the course of a few hours. Slender tubes would be seen growing from each grain and these would lengthen hour after hour. Fig. 12 will illustrate this phenomenon, *a*, *b* and *c* representing different stages in the development of a certain pollen grain. But where is the sugary solution to be found in the dandelion? The inner surfaces of the

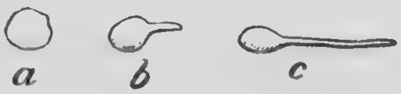

FIG. 12.

stigmas are roughened, soft, sugary surfaces. Should pollen grains reach these, the same kind of growth will ensue, only the tube will bore its way down through the spongy interior of the style until it comes to the chamber of the ovary, where the future seed, now merely an *ovule* is placed. In the covering of the ovule is a small gate called the *micropyle*, and through this gate the end of the pollen tube enters, and moves on until it comes into contact with the region containing the female germ cell. The liquids of the two cells, that of the pollen grain and that of the female cell blend and the work of *fertilization* as this process is styled, is completed. Fig. 13 will help to make this fairly intelligible. In this figure, *a* is the pollen grain, *b* the pollen tube, *c* the micropyle, *d* the female germ cell, and *e* the ovule. Only one pollen tube is necessary to reach the ovule, but one must reach it if the ovule is to be fertilized. After fertilization the ovule begins to develop until the final product, the ripened *seed* is the result.

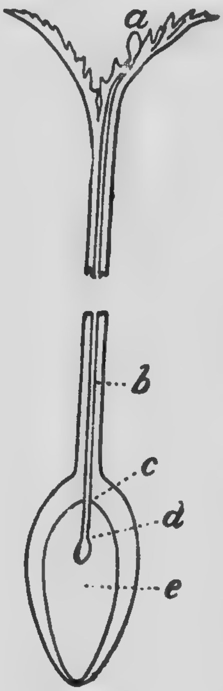

FIG. 13.

Pollination.—The dandelion, and many other plants, seem to object to using the pollen manufactured by the plant itself and prefers that the pollen should come from another plant of the same kind. *Pollination* in the dandelion, or the means by which the pollen is transferred from a stamen to a stigma, is accomplished by means of the many insects which may be seen in every dandelion flower cluster or *head*. These insects come to the dandelion flowers in search of the sweet *nectar*, a liquid secreted by many flowers; and occasionally for the pollen. The hairy bodies of these visitors get well dusted with pollen, and this pollen is carried from flower-head to flower-head, the result being that the stigmas of one dandelion may be pollinated by pollen from another flower. The dandelion also arranges to keep itself free from its own pollen. Look at a dandelion just opening. The outside florets are the only ones that have opened. The centre florets look like a miniature block pavement, because the rounded things filling the centre of the flower are the tips of the anthers. Inside the anther tubes the stigmas are placed with their stigmatic surfaces in contact so that no pollen can by any means adhere. In a few hours these stigmas push out and unfold. While this has been going on the pollen was being shed, but the only pollen caught lodged on the hairy outer surface of the stigmas (Fig. 14) where the epidermis or skin and the want of a sugary solution will in no way aid the pollen grain in its peculiar growth. Should no insect life place pollen on the dandelion stigmas, the plant in desperation, as it were, curls the stigmas backward

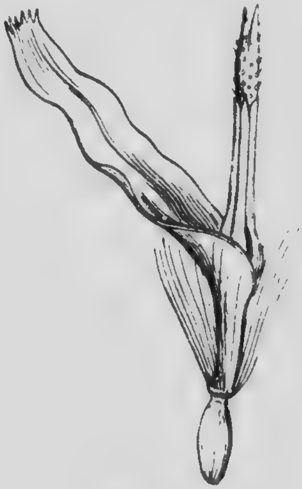

Fig. 14.

and secures self-pollination (Fig. 15). It seems, however, that better seeds and healthier plants result from *cross-pollination* than from *self-pollination.* Man has found this secret in studying nature's processes and has used it frequently in the discovery of some new grain, berry, etc. For example a late wheat plant bearing a good grain might, by pollinating its flower with the pollen of a wheat plant ripening earlier, give a plant that would possess the grain of the first and the earlier ripening qualities of the second.

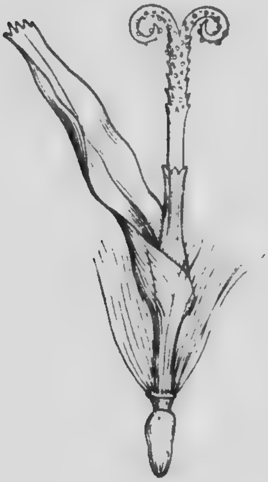

FIG. 15.

Transportation of Seed.—After fertilization has taken place the flower closes up and the green tent protects it from all danger. We shall now understand what is happening better than had we tried to answer this question earlier. The flower must have time to ripen its seeds and to prepare the means by which these seeds are to be transported from the mother plant's locality. The short neck, or calyx tube referred to, lengthens wonderfully, and in lengthening pulls off the corolla, the stamens, the stigmas and the styles, and shoves them out through the opening at the tent's top, like any bundle of old clothes. When the seeds have ripened, the tent walls fold back and the *receptacle* or end of the flower stalk curves so as to be convex above, thus forming the beautiful white seed ball mentioned before, and often seen and admired. What an impartial starting point for the dandelion children. All have the same chance of the friendly wind. One by one a seed is picked up and carried away, perhaps miles from its original home. How is it possible for these seeds to float and sail through the air? Here are where the silky hairs come in. They, and the tube connecting them with the seed, form a nice little parachute that the wind catches, and that the air buoys up and carries away. These seeds will come down by and by; perhaps in some friendly yard. The little hooks noticed in the surface of the seeds make good grappling irons, catching in the grass and holding the little seed. By and by these seeds get covered by the dust that is constantly being carried by the air, the rains make the earth soft, and the seeds sprout, catch the ground, and eventually become independent dandelions.

Germination.—To know how dandelion seeds grow you must place seeds in the germination-box and watch their progress. The seed is a living thing, and requires moisture, warmth, air and food in order to grow. It has all these. The moisture you have supplied in the wet blotting paper. The warmth is furnished by placing the box in a warm room. The air is ever present and the food has been stored up by the dandelion mother to help it along until it can get an independent grip of the ground. Dandelion seeds may also be planted in an ordinary flower-pot and every stage of their development observed. Seeds planted in September were in flower by the end of February. These dandelions were much more interesting apparently than nature's own sowing. Do you know why?

Looking at the dandelion now as a whole, what a wonderful mechanism it is. The leaves by growing so near the ground are not readily picked up by grazing animals. The bitter principle in the leaf substance is also a security, while the leathery character of the leaf as a whole will enable it to stand a very great deal of rough usage and still be able to contribute to the well-being of the plant. But these are not all the adaptations favorable to the plant. The fleshy root, the system of water-ways, the ability of the dandelion to live from year to year, the means of transportation of the seeds; these and many other features point to a most successful plant life.

That the dandelion is admirably adapted to hold its own in the tremendous struggle for existence taking place about us is very evident from the abundance of these plants found in towns and cities, and even now threatening the whole country. Most plants have a flowering season and a season for ripening the fruit. The dandelion has on the one plant flower buds just forming, flower buds just opening, flowers in full bloom, flowers bearing seeds, and flower stalks falling into decay. Such a plant, if at all noxious, is apt to be a particular nuisance, and the dandelion bears this out. Time and time again we have seen the owner of a nice lawn working almost night and day to rid the plot of the invading dandelions. Pulling was tried, but most of the root would remain in the ground only to throw out leaves again in the course of a few weeks. The table knife was also used and the rosette cut off, only to appear again when the owner of the lawn had been caught napping. Sulphuric acid and coal oil had also been resorted to, but dandelions continued to thrive and lawns to look as if dandelions had won the day. Can we not take a lesson from the dandelion itself? Does the dandelion not smother the grass and thus take its place? Can we not grow a plant that may smother out the dandelion? How about white clover? This will accomplish what is wanted. Should the mowing of the lawn result in again killing off the clover and bringing back the grass, which may in turn be invaded by the dandelions, the round of clover, grass and dandelion must be repeated. Such is the life story in part of a very remarkable plant, and every student has now the opportunity of adding to this story.

* **Weeds.**—Other weeds as well as the dandelion are a source of very great injury to the garden and to the field. No man has the right to allow things that may cause damage to his neighbor to breed upon his premises. But we cannot expect any intelligent observance of laws intended for the betterment of society if the facts of nature upon which those laws are based are not the common property of the community. Few people know even the names of the things that are doing the greatest harm or the greatest good in their own gardens. A weed persists in growing where it is not wanted. The most noxious weeds are those which possess such a vigor and such a tenacity of life that they almost defy dislodgment. Weeds are also great seed-makers and employ wonderful devices in securing the distribution of their seeds. Weeds likewise have a great deal of success in crowding aside and killing out all competitors. For these and many other reasons, weeds

should prove a most interesting group of plants to study. To encourage independent plant study we are going to ask that ten of the most noxious weeds of the locality be carefully observed and the results tabulated on the blank pages at the end of this chapter, according to the following plan:—

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* For weed study see "Farm Weeds," by Department of Agriculture, Ottawa.

Name of weed.	
Annual or biennial.	
Where found.	
Nature of damage done.	
How combated.	
Habits of weed that make it noxious.	

Questions.

1. What insects visit the dandelion flower? 2. Is the color or the odor of the flower the principal means of attraction? 3. What other inducements are offered insect visitors? 4. Make drawings of the leaf, flower-head, floret and root of a dandelion 5. In what particulars does a dandelion resemble a thistle? 6. Point out differences between a dandelion and a thistle. 7. How does the dandelion prevent self-pollination? 8. Write a short essay on the flight of a dandelion seed. 9. Why are so many dandelion plants found in towns and cities? 10. What are the functions of the root, leaves and flower of the dandelion?

THE LOCUST OR SHORT-HORNED GRASSHOPPER.

Structure—Head. If one would know the creatures met in the every-day life one must study them in their own setting and not depend entirely upon what others have said about them in the books.

In July, August, and the first half of September, grasshoppers may be secured and the characteristics of the adult noted. Examining, therefore, a short-horned grasshopper, we shall readily make out the three main divisions of the body, namely, the *head*, the *thorax* or middle region, and the *abdomen* or rear region. The head bears the *antennæ* (Fig. *16*, 2), two, long, jointed, slender organs attached in front of the larger or *compound* eyes (Fig. *16*, 1). The large eyes are really many eyes; each being six-sided in shape. Besides the compound eyes, there are three *simple* eyes, or *ocelli*. One of these is in front of the upper part of each large eye (Fig. *16*, 8); the third *ocellus* (Fig. *16*, 3) is in the hollow near the middle (Fig. *16*, 4) of the face of the grasshopper.

As grasshoppers are noted for their ability to remove vegetation, we should expect to find in the grasshopper's mouth the machinery for cutting and grinding foliage, and in its digestive system capital accommodation for preparing the food for the use of the body. Observing then the mouth parts, notice the movable flap-like upper lip or *labrum* (Fig. *16*, 6), situated below a wide, short plate, the *clypeus* (Fig. *16*, 5). Lifting the labrum, or removing it, if you are examining a dead specimen, you will find a pair of horny jaws or *mandibles*. Should you watch a grasshopper using its jaws you will find that these do not work up and down like human jaws. Removing the mandibles, you will discover a second pair

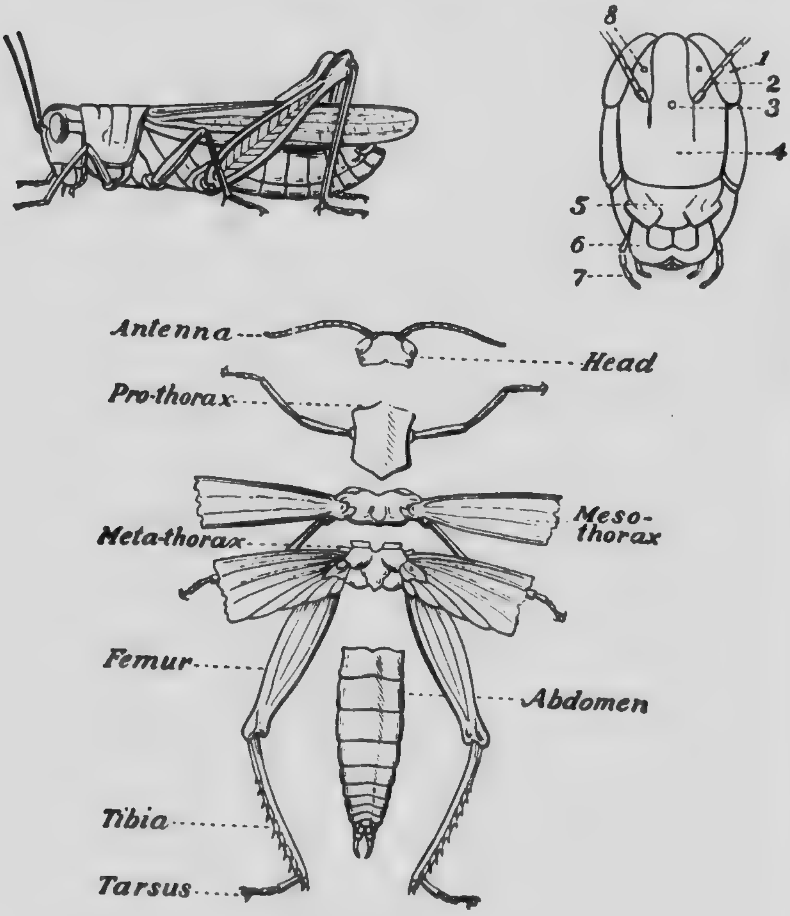

Fig. 16.

of jaws, rather complicated in their structure. These are called the *maxillæ*, and their motion is the same as that of the mandibles. Each maxilla bears, a five-jointed appendage, the *maxillary palpus* (Fig. *16*, 7). The lowerlip or *labium*, a sort of flap may now be bent back, thus revealing the spiny pad or tongue. The labium consists of a basal part the *mentum*, a pair of spoon-shaped pieces, the *liguli* and the two, three-jointed *labial palpi*, all of which may be seen in Fig. *17*.

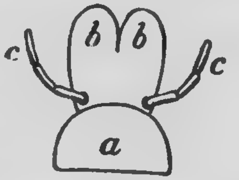

FIG. 17.

(*a*) Mentum. (*b*) (*b*) Liguli. (*c*) (*c*) Labial palpi.

Thorax.—Coming to the second region of the body, you will notice a continuation of the jointed appearance so prominent in the head. The thorax is divided into three regions, the *pro-thorax* or front region, the *meta-thorax* or rear region, and the *meso-thorax* or middle region. The pro-thorax, a sun-bonnet shaped piece, bears the first pair of legs. Observe how this piece fits toward the head of the grasshopper. The meso-thorax bears the first pair of wings and the second pair of legs, while the meta-thorax bears the large legs and the second pair of wings.

Wings.—The anterior, or front, or upper pair of wings form the *tegmina* or wing covers. These wings are about the same length as the insect's body. Each is a thin, transparent plate of *chitine* (the horny substance of the skin of an insect), and each is strengthened by a network of chitinous tubes, the *wing-veins*. The larger veins divide again and again into smaller veinlets, which interlace so as to divide the wing surface into a great many irregular areas or *cells.* The second or lower pair of wings are of the same length as the first pair, and when the insect is at rest are folded up under the latter. Their front edge is firm, the balance of the wing is parchment-like, and the numerous veins are so arranged as to cause the wings to fold upon themselves like the parts of a fan.

Legs.—The great leaping legs consist of five parts. The *coxa*, which joins the leg to the thorax; the *trochanter*, the *femur*, the *tibia*, and the *tarsus*. The femur is the large club-shaped part containing the powerful leaping muscles. When the insect is at rest the tibia extends downward and backward, and in the act of jumping it is thrown backward so that the leg as a whole becomes straight. The tarsus is made up of a number of divisions, which by their adhesion serve as a capital anchorage to the foot in leaping. All these parts are shown in place in Fig. 18.

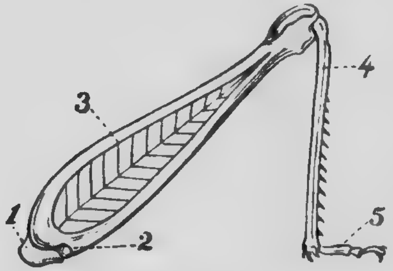

Fig. 18.

1. Coxa. 2. Trochante. 3. Femur. 4. Tibia. 5. Tarsus.

Breathing.—The abdomen is made up of a number of segments movable upon each other. In cross-section, this region would look something like Fig. 19. The typical number of segments appears to be eleven, although in both sexes there appear to be eleven *terga* or upper segments, but only eight *sterna*, or under segments in the female and but nine in the male. This, however, is but a small matter to the student who may

Fig. 19.

satisfy himself as to the number of these, and endeavour to square his count with that of the men who have given this insect a great deal of thought. Observe the opening on each side of the first abdominal segment. These are the animal's ears, a very strange position for ears certainly. In front of each is a small opening, the first of the *spiracles* or breathing openings of the abdomen. The remaining spiracles may be found out by a reference to Fig. 20.

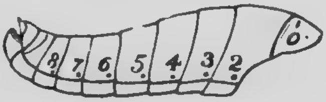

Fig. 20.—Showing the position of the spiracles.

The spiracles, we said, are the breathing openings. Within the body they divide and subdivide, bringing all parts into contact with the life-giving oxygen of the air. Notice the breathing movements of the grasshopper.

Sexes.—Should you examine the abdominal ends of a number of grasshoppers you will find differences which will enable you to distinguish the sexes. In some you will find four pointed, stiff needles or horns. There are in reality six pieces, but two are hidden from the view. In the remainder you will find a single hood-shaped plate. The first are the female hoppers, the strange rear structure being the *ovipositor*, an organ made use of in excavating the ground for the reception of the insect's eggs.

Grasshopper-Plagues.—Such is the external anatomy of the grasshopper. What a confusion of joints and plates! Was ever knight of old more encased in armor than this common nuisance of the meadow lands and grain fields? No one who has not witnessed the ravaging power of the short-horned grasshopper can fully conceive it. What do its strong jaws, its immense wing-power, its muscular body, mean when millions of these insects invade the country? Can a more destructive machine be devised or even thought of for removing vegetation from the earth? In the year 1857 grasshoppers destroyed all the crops of the Red River Valley, so that the young colony had to subsist by hunting and fishing. At this time the young hoppers appeared in such numbers as to "crackle beneath the feet of persons walking over the prairies." From 1863 to 1877 there was scarcely a year when grasshoppers were not more or less of a menace to the lands within the basin of the Red. Since 1877 grasshoppers have repeatedly threatened portions of the country, and, since history may repeat itself, farmers cannot expect to be always secure from the invasion of the worst species of grasshopper.

It is important, therefore, to know how and where grasshoppers breed, that intelligent action may be taken should conditions ever favor a future invasion of the country by these insects. Grasshoppers, we have with us every year. These may be studied in order to get acquainted with the general habits of this insect. We shall, however, keep before us, the life-history of the species that has done the country most damage in the past.

The Rocky Mountain Locust.—The *Rocky Mountain Locust*, whose home seems to be the western upland regions, may, if pressed by a scarcity of food, descend upon the lands to the east and ruin every grain field along the line of flight. The eggs of this insect are placed in holes in the ground. These holes are made by means of the two pairs of horny valves already mentioned; the valves being made to open and close much the same as certain post-hole diggers. After the hole is made the female fills it with eggs, and in order to secure these from the effects of the weather, she embeds them in a mucous material which hardens in a few hours. Fig. *21* represents such a nest.

While egg-laying and hatching may take place at any time during the summer months, the greatest effort at nest-making must be made in the early fall in order to secure the continuation of the species. In the fall of the year, therefore, the ground in certain localities may be literally sown with these egg-masses, which when hatched in the spring will yield thousands upon thousands of young hoppers.

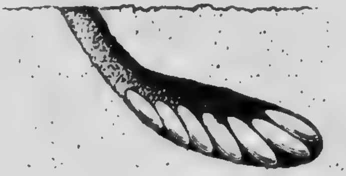

FIG. 21.

As the eggs in a particular pocket hatch at the same time there must be a considerable scramble on the part of the young grasshoppers to force their way to the surface of the soil. Should the land be ploughed before the hatching takes place, the eggs would be buried so deeply that few if any hoppers would ever reach the surface. Should the insects reach the surface what food can they get? They cannot fly, for their wings are mere pads. They must either walk to where there is food, or else starve. What time of the year would you suggest for this ploughing? Why? Like other insects, grasshoppers are obliged to *moult*, or throw off the old skin. Why is this? Note that the young grasshopper bears a distinct resemblance to the adult. There is no resting condition among the grasshoppers. The young are just as hungry as the old and are, therefore, as great a nuisance.

When about to get its wings the young grasshopper crawls up some friendly grass stalk or post, and after drawing its hind feet up under its body, grasps the support with might and main. In the course of a few hours the skin along the back and head splits and the full-winged insect gradually and very laborously withdraws itself, leaving the old tattered covering sticking to the post or grass-stalk.

Destruction of Grasshoppers.—Should winged grasshoppers invade the country, ploughing would be useless, but desperate remedies would have to be resorted to. A shallow sheet-iron pan, about eight feet long, two feet broad, and a couple of inches deep, is fastened to three runners, upon which it rests. At the rear of the pan, fastened upon a few uprights, a sheet of canvas is stretched, and the whole machine is pulled through the insect-infested field by means of horses. As the pan contains coal oil, a liquid particularly deadly to grasshopper life, bushels of grasshoppers are thus caught. Again, the oil soaked canvas prevents many grasshoppers from escaping by either knocking them back into the pan, or by smearing their bodies with oil. In both cases the result is the same. Recourse is also made to the numerous natural enemies of this insect, and also to its aversion to damp or wet weather. Grasshoppers delight in the bright, dry, summer season. In such weather they breathe more freely, become healthier and devour more. Grasshoppers show in many ways their dislike to dampness by climbing to the higher grounds and by seeking out the drier places everywhere. During rainy weather they feed but little, hence a long period of wet weather weakens their general health and causes them to fall a prey to certain bacterial diseases which frequently cut them off by the thousand. Grasshoppers affected by such bacteria climb the tallest weed stalks and die. After death their bodies set free the fine spores of the bacteria and these are carried by the air only to find lodgement on and affect other grasshoppers. Again, insect parasites of various kinds help the work of destruction along. Among these we may class the *tachina* fly, a fly resembling the house-fly in appearance. When grasshoppers are plentiful this fly may be seen endeavoring to fasten its eggs upon the neck and under the wings of some hapless grasshopper. The larvæ hatching from such eggs enter the grasshopper's body, feed upon its fat and eventually destroy their host.

Besides the enemies mentioned, we must not overlook the work of many birds and animals that feed heavily upon grasshoppers. Among these we may well consider the blackbirds, hawks and owls, the gopher, the skunk, the toad, and the frog.

Questions.

1. Compare the sizes of male and female grasshoppers. 2. Make a drawing of a grasshopper as seen from the side. 3. Compare the green grasshopper and the short-horned grasshopper. 4. Describe the liquid in the mouth of the grasshopper. 5. What is this liquid? 6. Why are the antennæ so movable? 7. Describe the compound eyes. 8. Can a grasshopper hear and see well? How do you know? 9. Cut a piece of paper the same size and shape of the wings and fold it as the inner wing is folded. 10. Can a grasshopper be drowned by holding its head under water? 11. Trace the development of a grasshopper from the egg to the adult.

THE HOUSE-FLY.

Flies in the Summertime.—The house-fly is known the world over as one of the worst of pests. In self defence we try to screen doors and windows; still flies continue to walk over our food, fall into our tea and milk, and make themselves a general nuisance. Flies are also a source of annoyance to cattle and horses, while their food habits may result in their carrying contagion from place to place. To combat such an insect successfully we must make a close study of its life history.

Flies in the Winter Season.—Flies, as everyone probably knows, are not winter-loving insects. Flies, however, must have some method of tiding over the winter and thus securing the continuity of the race. How is this accomplished? Many persons have wondered in a small way at the disappearance of flies in the autumn time and have attributed this disappearance to the frost. Others have been surprised at the return of the flies in the spring time. A few, a very few persons, have been really curious enough to piece this event and that together and thereby to discover just what has happened. Have flies not been seen about on warm winter days? Where have such been hiding, or have they hidden? Be on the outlook as the winter season approaches for the cause of the disappearance of the flies. Let nothing be considered too trivial to record. Here is one experience; dozens of other experiences may be added. On going to the central school, Brandon, on a certain Saturday afternoon in the autumn, the placing of the school-key into the lock set up such a buzzing that one could very easily imagine that a swarm of bees had taken up quarters in the lock. Dozens of chilly flies had simply done what all flies at this particular season do, namely, attempted to get into a warmer place. Flies driven by the stress of the weather, and also by their instinct of self-preservation, will find their way into houses no matter how snug the windows nor how tight the doors.

The Two Occupations of Flies.—Flies, like all living things, have two and only two great occupations. Flies look after themselves and flies provide, in a measure, for their offspring. All important questions about flies, therefore, centre about these activities. In looking after themselves, flies require food. Flies also have many enemies, and these they must be able to combat successfully. Flies must likewise be able to adapt themselves to changes in their environment. In caring for their offspring flies must deposit their eggs where conditions are favorable to the development of the young fly-larvæ. That all these are attended to is evidenced by the abundance of flies observed every summer, particularly during the months of July, August and early September.

In the springtime flies may be seen on any warm day walking lazily up the window-pane or flying in a blundering fashion from point to point in the room. These early flies act as if they had not any too much energy to spare. In a few weeks, however, one may be surprised to notice an increase in the number of flies, and an activity wanting in the case of the few which appeared at the opening of the season. The number grows rapidly until the midsummer fairly swarms with countless flies. Any insect possessing such marvellous powers of increase may readily prove a source of very great annoyance to human comfort if not easily checked.

House-Flies.—The common, or house-fly, lays its eggs in the rubbish of the backyard and in horse-manure. How many eggs each fly lays is a question no one has yet answered in a satisfactory manner. Here is an opportunity for the student. Possibly the female fly lays from a hundred to a couple of hundred or more eggs. These eggs hatch in a day or even in less time if the conditions be particularly good. These conditions are hot weather and fermenting rubbish. Indeed the blow-fly seems to be able to bring forth its young alive, for we have seen such flies laying eggs on cheese. Strange to say, these eggs were able to move about, a condition of things giving these maggots an advantage of some twenty-four hours over other flies. The *larvæ*, or as they are popularly called, the *maggots*, grow for about a week, and the *pupal* stage, or resting condition, takes up about the same time. Thus in from ten to fourteen days full grown flies, ready to continue the work of egg laying, may be produced a circumstance that easily explains how it is possible for ten generations of flies to occur in the space of a short summer season. For this reason a fly may be said to be able to eat an ox in less time than it would take a lion.

The house-fly has but one pair of wings, a feature common to all true flies. A closer examination, however, shows a small pair of winglets, which at first sight seem to be separate from the main wings. These secondary wings move very rapidly, and with them the *balancers*, short-knobbed threads that occupy the place of a second pair of wings, and which are supposed to be modifications of these, set aside for the purpose of breathing or hearing organs. If you wish to see these, catch a fly by the legs and watch the motion of the balancers.

The feet of the fly are armed with two claws, and each bears a couple of pads covered with hairs which secrete a sticky substance. By means of this secretion flies have no difficulty in walking up window-panes and across ceilings. The fly's feet are also useful at such times as the fly brushes himself and arranges his wings and body generally after being subjected to a bit of, what the fly might call, rough treatment. Fig. 22 will give a fair idea of the main features of a fly's foot.

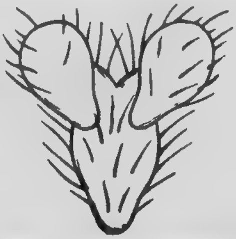
Fig 22.—Foot of House-fly.

The head of a fly has considerable movement. The compound eyes are placed so as to take in the surroundings well, a feature which may help to explain the difficulty one experiences in trying to get very near a fly. Do these compound eyes give the fly a distorted vision? Does the fly, for example, see the one object as many objects? Do you with your two eyes? Have flies any other than the compound eyes? Look the fly's head over carefully.

With the fly, the mouth parts are mostly suppressed or are rudimentary. The *labrum* is well developed into what may be called the proboscis. With this brush-like organ the fly easily sucks and laps its food, which must of necessity be given in solution. Prepare a sugar solution and endeavor [illegible] how flies feed. It is this organ that is the source of annoyance on a warm day. In what way?

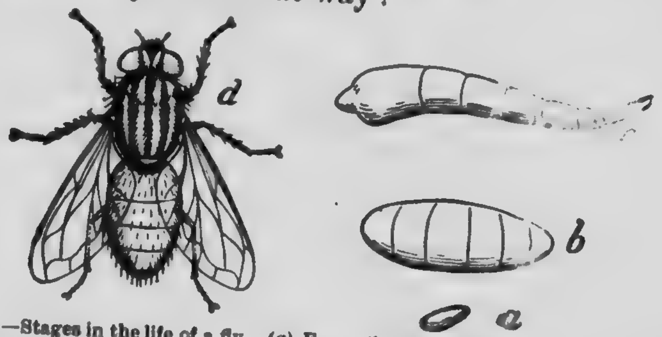

FIG. 23.—Stages in the life of a fly. (*a*) Egg. (*b*) Pupa case. (*c*) Pupa. (*d*) Adult.

The Stable-Fly.—The stable-fly closely resembles the house-fly. The mouth parts are adapted to biting instead of lapping, a feature all may probably be acquainted with. The stable-fly is the fly that is so troublesome to horses and cattle, and no doubt takes from them much blood in the course of the season, to say nothing of the loss of work in the case of the former, and milk in the case of the latter. These flies probably breed in manure heaps, a fact that may be turned to good account in towns and cities, but not so readily in the country, where manure may be spread on the fields.

Our study of the fly must not cease with a mere recognition of its form and appendages. It would be very interesting to examine the veins of the wings and to look into the peculiar outer skeleton of this insect. But the important thing is connected with the work of flies in the house and in the field. Flies are troublesome pests, but we have not touched upon the main thing, that feature which makes our study of the fly a very serious problem.

Scavengers.—Flies are among nature's best scavengers. We find flies swarming about the barrels and the boxes into which the refuse of the house has been dumped. It is here and also in the careless attendance of box closets that flies may become a source of very great danger to human beings. Flies must become contaminated with some of the material they feed upon, as this may contain disease germs. Just think of the number of typhoid fever germs a fly's foot, with its broad and hairy surface can accommodate. Think of these flies the next hour wading into the milk of the household. There is no better culture-material than milk. Think of a person in ignorance of what has happened, drinking such milk. Is there any wonder that typhoid fever stays about? Is there any wonder that the bite of the stable-fly is attended by more or less inflammation? These are serious matters: matters that would be lessened were people only conscious of the amount of danger that is wrapped up in so small a bit of life as a fly. Flies may be doing a very valuable work in removing decomposing material, but in doing this they may be the means of carrying disease. We may not eliminate flies from nature but we may lessen their power by covering up the garbage receptacles and exercising greater cleanliness about the premises. Were this attended to the world would be a better world, and the summer season would be robbed of one of its greatest terrors.

Questions.

1. Compare the house-fly and the short-horned grasshopper. 2. How many legs has a fly? 3. How are they attached? 4. Describe the egg, the larva, the pupa and the adult. 5. On each side of the thorax, just back of the head, find a spiracle. 6. Draw the fly as seen from above. 7. Will cold weather kill flies? 8. How long does a fly live? 9. Can you find out in what order a fly moves its feet? 10. What sounds do flies make? 11. Can a fly hear? 12. Can it smell? 13. Do flies, on the whole, injure man or benefit him?

THE CABBAGE BUTTERFLY.

The Canary-bird Vine.—Of the many climbing-plants people delight to place about their homes none is more interesting and few more beautiful than the *canary-bird vine.* This plant grows from seeds planted about the middle of May. It is a rapid grower, the foliage is a rich green, and the climbing-habit wonderful in its mechanism. It would be a good thing to encourage the growing of this plant in every school-yard. Many an unsightly woodpile could be turned into a bower of beauty by such a vine. There is just one objection in the way. The cabbage butterfly seems to be very partial to this plant, and has often selected its foliage as the safest and best place for its eggs.

The small yellow cabbage butterfly is usually common enough, but to have this insect where the whole round of life may be easily studied is not always an easy matter, unless such plants as the one mentioned be placed as a bait. Should such a vine be grown, it is altogether likely that evidences of the presence of the yellow butterfly will be abundant during the month of August and the early portion of the following month.

Butterflies are creatures of the summer and the summer-day. Rainy weather is not good weather for butterflies. The honey, or rather the nectar of the flowers, is their food, and they may often be seen flitting from one flower to another in search of this article. Butterflies may often be seen sunning themselves on the leaves or flowers. Watch the way they half open and close their wings. Watch two of the same species chasing each other. Note the advance and the retreat, the circling motion and the mounting skyward. Perhaps you may also see the yellow butterflies, to the number of a dozen or more, gathered about the margin of some drying puddle. On your approach they will all take to wing, but back they will come to the puddle-edge.

Catch a butterfly, and note the number of wings. These are thickly covered on both sides by overlapping scales. The scales are of different colors and are often arranged in patterns of very great beauty. To what extent is this noticeable on the wings of the cabbage butterfly? These scales are really modified hairs and each species may have its particular form of scale. Look at the insect's head. Its tongue is merely an instrument for pumping the nectar. Compare the antennæ of the butterfly and the moth. Does the body put you in mind of a caterpillar? What is its shape?

Egg-laying.—Now watch the cabbage butterfly as she dashes in and out, or moves here and there about the canary vine. She is egg-laying. Find out how she does this. Make a note where the eggs are situated on the leaf. Are they at the leaf-edge, on the upper surface, the lower surface, along the veins, are there more above than below, more on one leaf than on another, etc.? Can you see any advantage in scattering the eggs? Examine an egg. How is it attached? Scrape the outer covering away. What is this covering for? While searching for the eggs, look also for signs of the caterpillars. These signs will be leaves more or less eaten into. Examine these leaves for the purpose of determining whether the caterpillars have any system in selecting the portions of the leaf to be devoured. The caterpillars themselves are not easily seen. Should you find them, make a study of the various features which aided in concealing them so well. To what extent do they wear the livery of the thing they feed upon? Watch the caterpillars feeding to find out whether they have special feeding hours and resting hours. How does the weather affect them? How many legs have they? You will find two sets of legs; one set on the thorax and the other set on the abdomen. Which of these are the true legs? What is the purpose of the other set?

The Chrysalis.—When the caterpillars have attained their full size, place a few in a paste-board box and continue to feed them with leaves taken from the vine. In a few days you will open the box to find several, or all of the caterpillars wonderfully changed. You will find instead of the insect you placed in the box, something like Fig. 24. This is the *pupal* stage of the life of the cabbage butterfly. To prepare for this the caterpillar had to feed voraciously so that abundant fat would be stored up. When ready to become a pupa or *chrysalis*, so called because of the golden spots that mark the pupæ of many butterflies, it spins a mass of silk which it uses to fasten itself to some friendly wall, ceiling or even pantry. The whole process may be readily made out should the student be fortunate enough to discover a caterpillar at work. The marvel is that so awkward a creature can do a piece of work so fine.

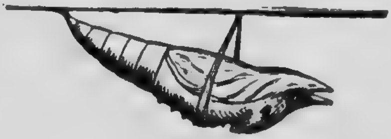
FIG. 24.

Should the caterpillars reach the pupal stage about the end of August, or at the farthest, during the first week of September, the chances are that the final stage of the butterfly-life may be reached in a week or ten days. Do not be disappointed if this does not happen until the following spring. Place the box in a room where the temperature will not vary much, and exercise sufficient patience until spring may have time to bring the reward. A study of the cabbage butterfly is practically a study of every moth and butterfly; all pass through the stages of egg, larva, pupa, and imago or fly.

The Remedy.—As the caterpillars of the small, white, cabbage butterfly bore into the cabbage heads and thus make the application of the usual Paris green insecticide dangerous, it may not be out of place for the student to become acquainted with a better remedy. The cabbage caterpillar is really one of the easiest pests to bring under control. As soon, therefore, as any cabbage butterfly larvæ are noticed, dust the cabbage plant or the canary-bird vine with a mixture of one pound of pyrethrum insect powder, mixed thoroughly in four pounds of cheap flour, and placed in a tightly closed jar for twenty-four hours. The powder is then ready for use and may be dusted over the plants with a cheese cloth bag tapped lightly with a slender stick. The value of this remedy is its harmlessness to human beings and to the higher animals.

Questions.

1. Spread the wings of the butterfly and draw them as seen from above. 2. Write an account of the life history of the cabbage butterfly. 3. Compare the butterfly and the grasshopper; the butterfly and the house-fly. 4. What is the difference between a butterfly and a moth? 5. Study the life history of the clothes moth. 6. Can you distinguish male from female butterflies? 7. Would you expect a difference in color here? Why? 8. What is the difference in the ways moths and butterflies light upon flowers? 9. What are the enemies of the cabbage butterfly?

THE SPIDER.

The Spider's Bite.—Among the multitude of insects of the field, none are perhaps more dreaded by people in general than the spider. Spiders' bites are considered fatal; or if not fatal, more or less poisonous and to be avoided if possible by giving spiders a very wide field. For this reason people have not given the spiders a fair chance. Had spiders this chance we feel assured that they would give a much better account of themselves than is commonly reported. It is true that spiders can bite. If they could not do this they would have a very serious time trying to live. It is also true that spiders ensnare flies and other insects and insert poison into the wound inflicted in order to make sure of their prey. But it is not true in the case of northern latitude spiders at any rate, that this poison is a menace to human life. The tarantula is shunned and rightly so, but our house and field spiders belong to no such class. The spiders we shall study are practically harmless, but this does not mean that we are encouraged to catch spiders. Leave the spiders alone at their work if you would know something of spiders. As our study of the spider develops we think we shall all agree that the spider has not deserved the many evil things ascribed to it by tradition, superstition and ignorance. We shall find as we go along that the variety of dried-up skeletons found in almost every spider's web suggests the spider's varied bill of fare; that the spider does much to keep in check many insect pests, and hence must be regarded as man's friend instead of his enemy. We shall also find that the distribution of the spider is very extensive. Spiders are found almost everywhere. A few live in the fresh water. The remainder live upon the land and almost all live upon the juices of insect life. One needs to give good heed who would learn to know how large a part spiders really play in nature's economy. Spiders are among the most numerous of the tenants of the earth, and a fair idea of their number may be guessed by the webs seen on the grass on dewy mornings. Indeed, the whole landscape is covered with the handiwork of spiders, and there is scarcely a spot where spiders have not secured a home. To supply so great an army with food is no small thing, and the insect life destroyed must be enormous.

Orb-weavers.—Spiders may be divided according to habits into wanderers who spin but little, and home-makers who spin a great deal. As one of the most important uses made of the thread is web-building, and as spiders are often known by the character of the web built, a few observations along this line may be of service. Who has not seen the web of the *orb-builders*. Few, if any, structures are more wonderful, but these webs are so common that little is known regarding their construction. Most people know that these webs are somewhat like a wheel, but this is about the extent of the general knowledge.

The orb-builders first select, we may suppose, a suitable spot along some insect-travelled highway. Having made a choice the foundation-cables are put into place.

These are marked in Fig. 25. How are they put into place? The next move is to swing the first *ray* line across and fix this securely. Indeed, no bridge builder could be more careful than the orb-weavers seem to be with their main threads. Another and yet another ray is put into place, and all are made to intersect at the centre of the web. Starting from the centre, the weaver moves from ray to ray in a spiral, and fastens the thread to the rays as he moves along. On reaching the circumference the spider works backward toward the centre, leaving a much closer spiral, and biting off the former

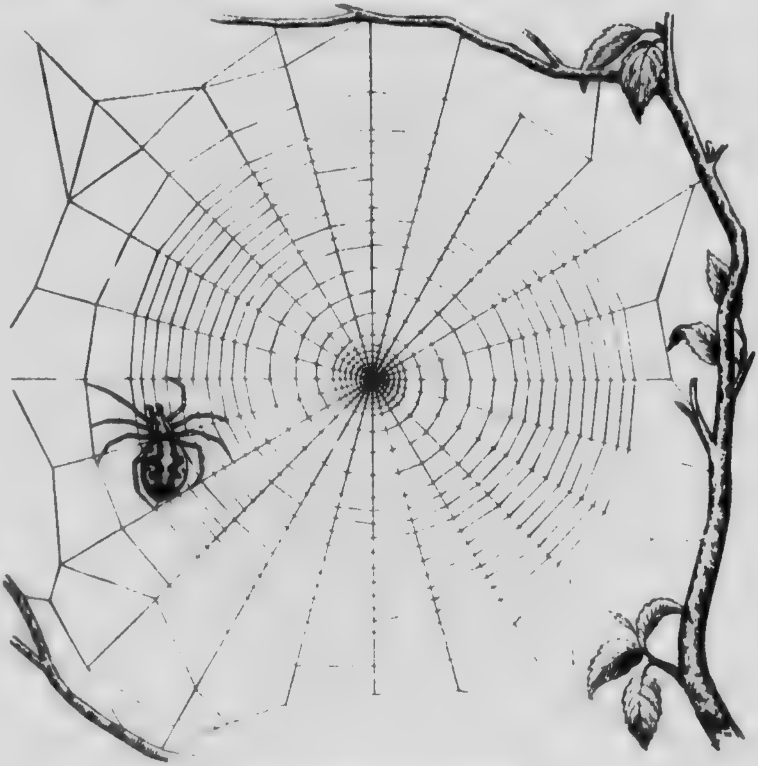

FIG. 25.—Web of Orb-weaver.

temporary one. The second spiral is more viscid and adhesive than the first. Usually the web is completed by placing an irregular ribbon of silk over the centre. This the spider makes by keeping the spinnerets well separated. Sometimes the owner rests upon this centre and waits for some passing insect to blunder into the web.

Other orb-weavers have a retreat into which they go. This, however, communicates with the web by means of certain main threads which vibrate whenever something has been caught by the meshes of the main web. When an insect falls into the web it is bound to come into contact with a part of a sticky line (all the lines need not be sticky). The line adheres; the insect struggles to free itself and likely touches a second line. By this time the master of the house has arrived on the scene. Why was he not caught in his own web? Observe his behaviour toward a captured fly.

The Cob-web Spider.—Another common spider is the *cob-web weaver* of the house. What a nuisance this spider is to the careful housekeeper. How persistent the cob-web weaver is in building again and again after the web has been swept away by the merciless broom. The web of this spider has not the artistic finish of the orb-web and may be viewed as a shapeless maze of threads. It is, nevertheless, well adapted to the snaring of insect-life, there being abundant evidence of this fact in every one of these webs. In studying these webs observe how the spider moves about in them, and also whether the place selected is or is not favorably situated for the spider's business.

The Funnel-web Spider.—Another spider is the *funnel-web weaver* or grass spider. Often in summer mornings the grass seems to be covered with a great many little sheets of shiny silk. Perhaps none of us even suspected that so many spiders were in the neighborhood, but the drops of dew aided our observation. On examining one of these we shall find that it is a closely woven sheet made of threads running in all directions; that it is attached here and there to spears of grass, and supported by numerous guy-lines; and that from one side a funnel-shaped bag reaches downward. This funnel gives both web and spider their names. The funnel is the spider's place of retreat; it has a back-door communicating with the open world, a capital place when the owner is hard pressed. These are some of our commonest spiders. Others may easily be added by the student.

Cephalo-thorax.—The spider's body reminds us of the body of an insect, but the spider is not a true insect. Count the spider's legs for instance and compare this number with the six legs of an insect. In the spider, head and thorax are more or less united into one piece, called the *cephalo-thorax.* The abdominal part is separated from this portion by a very narrow waist. The hard, horny covering varies in coloring and hairyness and is renewed by frequent moults. Should you come across such a coat, examine it in order to determine how it was removed.

Head. Spiders have two pairs of jaws which move sidewise like the jaws of certain insects. The first pair are called mandibles. Each mandible consists of two segments, a strong segment at the base and a claw-shaped one at the end. At the tip of this the poison gland opens. The second pair are the maxillæ. These are placed just behind the mandibles and each bears a large feeler or palpus. These palpi vary very much in form and often resemble a fifth pair of legs. In the male spiders the last segment of the palpus is more or less enlarged and ends in a knob-like structure. In this way the sex of the spider may be readily determined. Most spiders have four pairs of eyes. These appear as very bright spots on the front of the cephalo-thorax.

The Spinning Machine.—The most characteristic feature of spiders is their spinning apparatus. The silk is an organic substance, that is, it is made by a living thing, just as Japanese silk is made. The silk is secreted in glands within the abdomen, and, while in the body, is in a liquid condition. The spinnerets, which are movable organs, may be seen in the rear of the spider's body. These are perforated by numerous fine tubes which connect with the silk glands. Compression of the silk glands causes a flow of liquid-silk through the fine tubes (spools) of the spinnerets. These delicate threads unite by contact and not by winding and form a compound strand of wonderful strength. An ordinary thread, a thread just visible to the naked eye, is a union of a thousand or more of these delicate streams of silk. Occasionally the several threads of the spinnerets combine to form a much stronger thread. These primary threads are drawn out and united by the spider's hind legs. Before beginning to spin, the spider often presses the spinnerets against the surface to which the thread is to adhere, and draws the filaments out by slowly moving away. The legs are made much use of in extending and guiding the thread, and some spiders have a special comb of stiff hairs on their hind legs. The purpose of these hairs is very evident. Figure 26 may be of some assistance to the student in locating the various features mentioned.

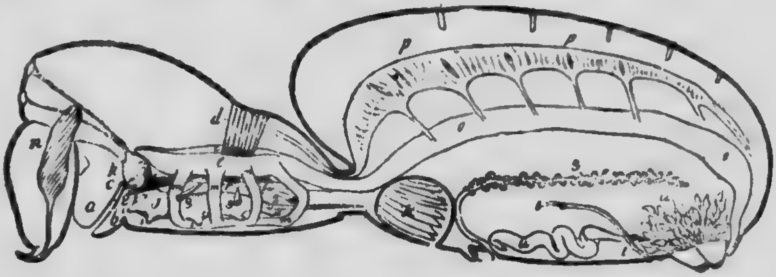

FIG. 26.

Spider-motherhood.—With spiders, the mother's care usually ends in laying the eggs and safely disposing them in a bag or cocoon of silk. You may find these very elaborate bags attached to the webs, to stones and also under the loose bark of the trees. The sacs attached to stones are disk-shaped, silvery objects. Those of the orb-weavers are placed in the web and those of the cobweb weavers in various places. Should you find one of these bags, watch it closely. Find out if the young spiders undergo a metamorphosis somewhat similar to that passed by the mosquito, the house-fly and the butterfly. Look also for any signs of cannibalism in these spiders.

Various interesting experiments may be made with spiders. The following is suggestive:—

Stick the nib of a pen in a potato and set the two in a bowl of water, the pen-stalk being kept in a vertical position. Pour water into the bowl until the potato is just covered nicely. Place a spider on the mast-head of this submerged vessel and see if the spider can get ashore. If the spider should not succeed in the course of a day or so, set the bowl on the window sill; open the window a few inches and observe what will shortly happen.

Value.—Spiders injure no plant-food or other product of human industry. In the pursuit of their daily work, spiders are not only without hurtful qualities, they are also engaged in a ceaseless warfare upon the enemies of man's comfort, success and general well-being. Even when spiders invade our homes they do so to rid the house of what may be dangerous insect guests. No one who has made even a partial study of the work of spiders can speak disparagingly of this work, and it is a pity that these benefactors of our common humanity should be the subjects of ignorant hate and slain at sight.

Questions.

1. Can a spider crawl out of a tumbler? 2. Compare the spider and the grasshopper. 3. Is a young spider like the adult? 4. What have you seen spiders do to the insects captured? 5. Describe any spider's web that you have studied and point out any advantages secured by its position. 6. Point out the features that make the spider the friend of man. 7. Tarantulas are sometimes found in the colder temperate zone. How do you account for this?

THE MOSQUITO.

The Importance of the Common Things.—The *common* things of the everyday life are the things no one can afford not to know, and among these we must include that pest of the summer season the mosquito. Mosquitoes may be seen during any month of the year by the favored few who have learned to observe. The rest of mankind learn of the presence of the mosquito only when a peaceful summer evening's rest has been disturbed by this insect's visit. The question of what becomes of the mosquito during the winter season is a question that tries to explain how the mosquito bridges over the gap from one summer season to another. To answer this we would suggest that students take a passing interest in the various insects that have gone into some friendly cellar to pass the winter.

Many species of the mosquito inhabit the continent of North America, but it is only necessary for us to learn the life-story of one species. The best time for our study is during the months of June and July, or when the mosquito-season is at its height. At such times one does not usually need to be told that mosquitoes are abroad, for the mosquitoes will attend to this matter even too closely for personal comfort.

Egg-laying.—All life begins in the egg. This is just as true of the mosquito as it is of the hugest animal the world has ever reared. But where shall mosquito eggs be found? Should you expect to find the eggs in a wet place or in a dry place? Have you ever taken a walk through the long grass during the mosquito season? How did you account for the myriads of mosquitoes that you stirred up in your walk? How do you suppose these insects got there? Are mosquitoes more partial to cloudy weather than to sunny weather? Do they show any special preference for a particular part of the day? Are more to be found during a wet season than during a dry season?

To get the eggs place a pan of rain-water in the open air on the lee side of the house, and let it remain there throughout the night. In the morning you will likely see what appears to be bits of soot on the water-surface. These are the eggs of the mosquito. Remove them with a teaspoon, and place them in a tumbler two-thirds full of rain-water. Examine the egg-mass with a small hand lens. Note the shape and point out the advantages of such a shape. How many eggs form one egg-boat or egg-raft? Is this number to be depended upon? Detach one of the eggs. Observe its shape and satisfy yourself that such a shape fits into the boat-shape of the mass. Can you make out how the eggs are protected from the water? Look for mosquitoes' eggs on the surfaces of puddles, ponds and quiet waters generally. An old tin can with a little water in it may be the breeding-pond of the mosquito. Find out whether the egg-masses are found in such places as would expose them to the wind and thus upset them. Invert one of the egg-masses and observe whether any serious results follow. How did the mosquito place the eggs in the raft? What keeps the eggs together?

Larvae.—To study the development of the eggs, cover the tumbler with a piece of cheese-cloth and do not place it in a window where the water might get too warm. Why are these precautions taken do you suppose? As the eggs were probably layed in the early morning, you should be able to determine how long mosquito eggs take to hatch, and to what extent the weather conditions hurry or retard the process. Be sure to watch just how the mosquito *larvæ* escape from the eggs.

The next stage is the well-known "wiggler" stage. This stage shows two wiggler forms. The first form is what is called the *larval* stage, and the second, or more developed is the *pupal* stage. These forms are pictured in Figs. 26 and 27.

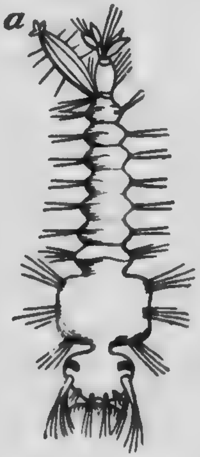

FIG. 26.—Larva.

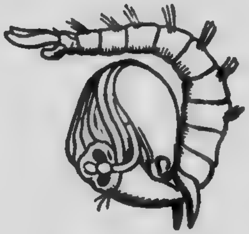

FIG. 27.—Pupa.

What shall we look for in the first of these stages? Look for the cause of every movement on the part of the larvæ. Satisfy yourself of the fitness of these little animals to their mode of life.

Feeding.—Mosquitoes and their young are often seen in and about rain-water barrels. They would not be found there if rain-water did not contain food of some kind; but what food? Have you ever observed the amount of black mud that lies at the bottom of rain-barrels? Where do you suppose this came from? How does it affect the purity of the rain-water? What makes the water of such barrels smell so offensively? Perhaps you now see where the wigglers get their food and why the mother mosquitoes were so partial to the rain-barrels. This food is microscopic in size and consists of decaying vegetable matter and the microscopic forms of life that are sure to infest such water. How does the wiggler take his food? A hand-glass cautiously held near the wigglers will probably make the process plain enough. The hairs about the wiggler's mouth are in constant motion and hundreds of small particles of food are carried into the insect's mouth.

Breathing.—Do the wigglers breathe like a fish or do they breathe like a land animal? Watch them come to the surface. Is this a labored process or is it done easily? Find out just how the breathing takes place. Notice that the tail-end of the insect is the end that touches the water-surface. What does this mean? Notice the projection, (*a*) of Fig. 26. This is the *syphon* or breathing tube. The syphon ends in a rosette of five plate-like lobes, which, when they reach the surface, spread out, thus helping the buoyancy of the wiggler and at the same time giving it more air. Endeavor to keep the wigglers from the surface. At first they are frightened, but the approaching suffocation forces them to brave every danger and up they will come.

The larvæ of the mosquito develop very rapidly providing the weather conditions are favorable. After a few *moults* the awkward shaped pupa, with its greatly enlarged head and thorax is the result. When this stage is reached make comparisons of the two forms. Which is the more active? Which form rises to the surface the easier? Which goes to the bottom the easier? What do you infer from this? Notice the wings-pads on the sides of the thorax of the pupa. Do the pupæ make the same use of the surface of the water that was made by the larvæ? The pupal stage lasts but a few days. Indeed, in ideal weather and abundant food supplies both stages are covered in from seven to fourteen days. Is there any wonder that mosquitoes soon appear in myriads? Watch for the emergence of the fly. The skin of the pupa splits down the back; the winged insect carefully works itself free, and after using the cast-off shell as a raft, dries its wings and then flies away.

The Adult.—While engaged in studying the development of the mosquito from the egg do not forget that the adult mosquito has many features worth observing. Note, therefore, the three sections of the body and find out which division bears the legs and which the wings? How many wings has a mosquito? Notice the veins. What do you think these are for? Do you see the hairs at the margin of the wings and on the wing-veins? Examine the proboscis. What is seen is the sheath-like *labium* or lip. Within this are six fine needle-like organs which the mosquito uses for piercing the skin. Fig. 28 will make this plain.

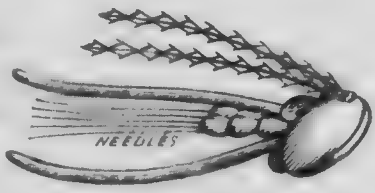

FIG. 28.

Take note of the position of the mosquito's legs when in the resting posture and also when engaged in blood-letting. Examine the antennæ with a small microscope and compare with the cut given under Fig. 28. How far is the cut an imperfect one? How far are mosquitoes sensitive to sound? Is there anything in the saying that an animal able to make a sound must also be able to hear sound? Do mosquitoes appreciate odors? What evidence have you been able to collect on this point? Do mosquitoes seem partial to color? Do they attack for example, persons in black more readily than those dressed in white? Do they fly far? What do you know of their speed in flight? In how far is their behaviour guided by weather conditions? Can you distinguish between the male and the female mosquito? Look for a difference in antennæ and a difference in proboscis. The antennæ of the male are very feathery and the proboscis is not adapted to the sucking of blood.

Place in Nature.—After having studied the round of life of the mosquito, it will be interesting to make a few general observations as to the place this insect occupies in nature. All living things must subserve some useful end or be finally eliminated in the process of advancement. In the long run, the weak, the useless and the harmful must perish. This is nature's inevitable law, and so far as man aids in enforcing this law, he should do it mercifully. To whose benefit must the world of nature finally contribute? There can be but one answer to this question. Man, standing at the head of the animal species, rightfully claims sovereignty over this great kingdom and demands that the brute creation as well as the domain of plants shall in the long run, subserve his ends. To exterminate any animal or plant thoughtlessly is a dangerous process. All life is sacred and should never be extinguished except when necessary. But nothing has the right to interfere with the rights of another, and man determines when one thing has overstepped its proper bounds. Man determines what helps and what hinders the advancement of the world and the well-being of the human race, by studying the life-histories of the various forms of life, and so learns the power of each for good or for evil. With this standard in mind, try to sum up what the mosquito does for the general betterment of nature. To assist in this, we would ask students to make such experiments as the following:—

Take two tumblers of water from an old rain-barrel. Place wigglers in one and leave the other unstocked. In a few days test the two samples for color, smell and general purity. It will be found that the tumbler containing the wigglers is the more wholesome of the two. What has taken place? What statement can be made as to the work of wigglers? Is there much need that such work should be done? Can this difficulty be remedied by any other means than the assistance of the larvæ of the mosquito?

On the other side, gather all the information available as to the extent to which horses, cows, human beings, etc., are annoyed and injured by the presence of the mosquito. Is the piercing apparatus of the mosquito likely to be as free from injurious matter as a surgeon's knife ought to be? What may be the effect of making even a small wound with an instrument that is not disinfected? How do mosquitoes affect horses and cows? Does this make these animals better able to do the work expected of them? Does the work of ridding the waters of the neighborhood of their poisonous tenants counterbalance this discomfort and loss?

Place wigglers in the aquarium with the tadpoles and the other creatures. What happens? Does this justify the continuation of mosquito life in any way? Should your work lead you to the conclusion that the mosquito really does more harm than good, how would you suggest an improvement?

Place a few wigglers in a small bottle of rain-water. Drop in a few drops of coal oil and note results. Explain what has happened and show how this may be used to rid the ponds of the neighborhood of their wigglers. Is there any objection to this plan? Can you suggest another, a plan that is based upon the fact that dry seasons are unfavorable and wet seasons favorable to mosquito life?

Questions.

1. It is said that mosquito seasons are good wheat seasons. Explain. 2. Compare the mosquito and the fly. The mosquito and the grasshopper. 3. What is the mosquito hawk? 4. What is the adult mosquito's natural food? 5. What have you read of the mosquito and malaria? Of the mosquito and yellow fever? 6. Write an account of the life-history of the mosquito. 7. How long does a mosquito live? 8. Why are mosquitoes so numerous in the summer weather?

THE SCHOOL AQUARIUM.

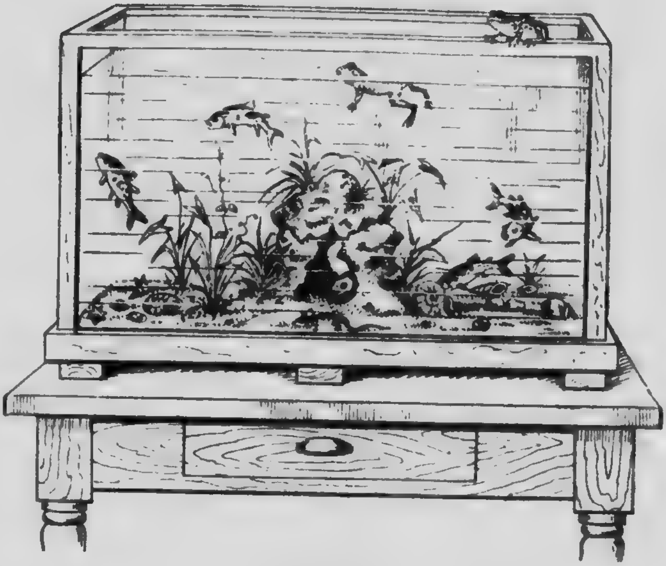

Fig. 29.

Pond Life.—Animal life is not confined entirely to the earth and the air; the water, too, has its own special forms, but much of this ordinary people are ignorant of because they have never taken the trouble to learn some of the secrets held by every pond, slough, creek and puddle. To study pond life properly one requires something else besides leisure to spend hour after hour watching the various water-loving creatures. Such a study is of course necessary, but young students will do better work and have greater success if the pond be supplemented by the school-pond or aquarium, where the behaviour of certain pond snails, fish, tadpoles, etc., may be studied more leisurely.

The term *aquarium* often suggests a strange-looking glass bowl containing goldfish, impossible rockwork and curious water plants. Such aquaria may be of value as an adornment to the home, and a source of entertainment to the family; but the aquarium we have in mind is for use rather than for ornament; it is for the student's special work, and few things are more interesting than a properly constructed and carefully managed aquarium. Such an aquarium can not care for itself any more than can a kitchen. Some little care must be taken, yet few things are less troublesome to keep in order when once set up. Care must be given regularly and daily, for without this attention the best aquarium may become an unsightly and disagreeable object, its inhabitants unhealthy and its usefulness gone.

Making the Aquarium.—The best aquarium for the school is not the costly tank that may be purchased from the dealers of such articles. The best tank is the one that represents the constructive genius of the class and teacher. How to make such a tank is a part of the purpose of this chapter. A cheap, substantial aquarium may be made of window-glass and angled tin. The glass is easily obtained, and any tinsmith will know how to cut and "angle" the tin for the framework. Candy jars, fruit jars, even tumblers may come in as temporary aquaria and for individual service. The class aquarium should be at least fifteen inches long, ten inches deep, and eight inches wide. To complete this we require two plates of glass 15 x 10, two plates 8 x 10, and a bottom plate 15 x 8. In every case the glass should be of double thickness. The tin for the framework should be cut from three-quarters to an inch in width, and the strips should be angled and soldered by a tinsmith.

To set the glass in the frame, cement is needed. Several varieties of aquatic cement are made use of, among which are the following:—Ten parts each by measure of fine, dry, white sand, plaster of Paris, litharge, and one part powdered resin. These ingredients should be well stirred together, and, as wanted, mixed to the consistency of a stiff putty with pure, boiled linseed oil. This is said to be a quick-drying cement, but it may become a little too hard. Another cement somewhat similar to the above omits the plaster of Paris and the driers. A third cement is obtained by taking one part pitch and one-fourth part gutta-percha, and applying warm. These should be melted together in a large iron spoon over a gas flame or the flame of a large spirit lamp. This is a serviceable cement, particularly if any portion of the aquarium has been made of wood. A fourth cement consists of red and white lead, the two being mixed together into a stiff paste. The bed for this cement should be painted with gold-size. Having prepared the cement, lay it on evenly all around the bottom of the frame and press the bottom glass into place. Put the sides and ends into position in the same manner, and brace them by means of bits of thin lath or twigs until the cement has had time to set. Paint with black lacquer the whole frame, but particularly that part of the frame that will be exposed to the water.

Any aquarium requiring cement should stand filled with water for a week or ten days, and this water should be frequently changed. This is a good test of the aquarium and it also ensures a perfectly clean home for the creatures which will shortly occupy the tank. When sufficiently tested and seasoned the aquarium should be emptied, washed and placed in its permanent situation; the latter by no means an easy problem to solve for the light must not be too strong for the animal life nor yet too weak for the aquarium vegetation, should this be introduced.

To fill the tank, put in clean sand to the depth of from two to three inches. It is important that the sand should be clean. Should the sand, therefore, be procured from the river-bed or even a sand-pit, see that it is washed off all impurities by adding clean water, stirring the sand up and pouring off the muddy water until the water becomes quite clear. Cover the sand with a layer of gravel and plant such vegetation as you think necessary before adding the water. Add the water slowly so that the sand and the plants may not be disturbed. To accomplish this satisfactorily follow the suggestion given by the accompanying cut. Fig. 30.

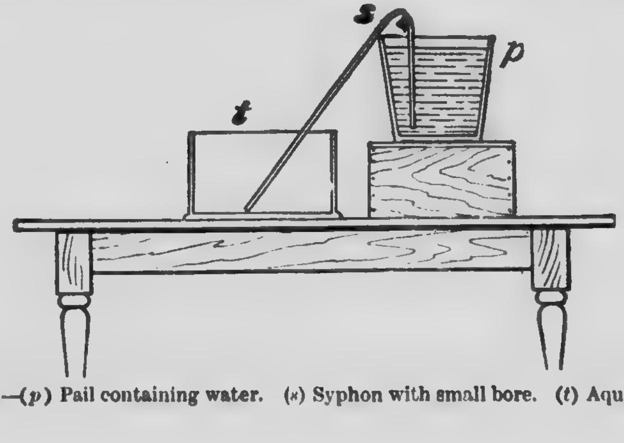

FIG. 30.—(p) Pail containing water. (s) Syphon with small bore. (t) Aquarium.

In an aquarium, properly arranged and cared for, the water should seldom require changing if such water be taken from the best possible source. The best water for aquarium purposes is good river water; next comes the water of a large and clear pond; next, rain-water, and finally, if at all, hard water from a well. After reading the directions given, and getting the idea of an aquarium, think out the whole matter for yourself and make the very thing you feel you require most of all. Directions are useful only in the way of suggestion. The shallow aquarium is better for toads, frogs and aquatic insects, or those forms of life that may not care to remain in the water all the time. The deeper aquaria show water plants and fish to better advantage.

Stocking.—We have taken it for granted that aquatic plants of some kind should be present in an aquarium. This is not necessary where the aquarium is meant to harbor life for a few days at a time only. It is, however, of prime importance when the aquarium is to house animal life for several weeks at a stretch. The reason for this is seen by even a casual observation of any natural pond where animals and plants grow up together. Animals do not thrive in water where no plants are growing. Plants supply food for the herb-loving water animals. Plants give off oxygen which the water retains and which is necessary for certain kinds of aquatic animal life. Furthermore, plants take up the carbon dioxide gas which escapes from the bodies of the animals, so that plants and animals are here mutually helpful.

In stocking an aquarium with plants, we must bear in mind that there is such a thing as an *equilibrium*

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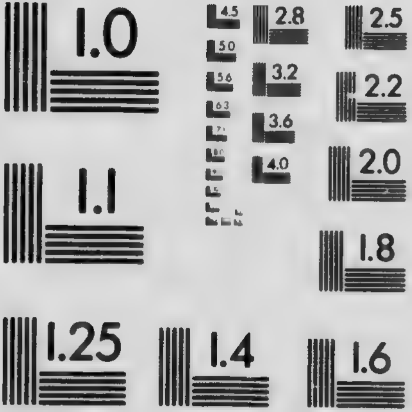

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between plant and animal life and that this equilibrium must not be interfered with. If too many plants are permitted to grow in the aquarium, there is bound to be too much shading, and therefore more or less injury done to the animal life. If the plants are too few, the removal of the carbon dioxide and the addition of oxygen will not be properly secured, and a green scum or algæ, a vegetable growth, will soon cover the water surface and injure the aquarium.

We have mentioned that the introduction of plants may not be a necessity. Indeed, we have often seen a whole class of boys and girls enthusiastic over the queer capers of a few water boatmen in a fruit jar. But half the pleasure of owning and caring for an aquarium would vanish were no plants thought necessary. Plants give to the tank nearly all its beauty, and water plants have some features of their own that should prove most interesting to the students. Almost every aquatic plant may be grown in the quiet water of an aquarium, and may be made more or less useful there. Many of the common pond or marsh plants are suitable, particularly such plants as would never grow too large for so tiny a pond as the school aquarium. Mill foil, water purslane and stonewort, in fact, any small, feathery water-loving plant will answer the purpose.

What animal life should be added? Is not the purpose of the aquarium to help us to get better acquainted with the variety of life inhabiting the neighboring ponds and streams? Should we not add anything in reason that may be caught by an old tin pail or by a minnow net? We shall study all, but we shall endeavor to find out just what animals it would do to place together in the tank. Have you ever heard of the expression, "a struggle for life"? Every species of animal, lives if at all, by a struggle at some period of its life. The meekest creatures must fight, or die, and to this rule there is no exception. If the increase [illegible] example, of even the human race were not checked, there would not be standing-room for the descendants of Adam and Eve. The main check to increase are *climate*, acting on the food supply, and other *animal life* in competition for the same thing, or enemies preying upon one another. You will see evidences of this struggle going on even in the narrow limits of the glass walls of the aquarium. There are some animals which would prey upon their smaller or weaker neighbors, and even upon members of their own families. Should you, therefore, wish to have harmony in the tank, be on the watch for any predaceous animals you may have taken out of the pond and place them in a tank by themselves.

Should you like to know something of the life of even a very small fish? We have seen a little fish scarcely an inch in length delight scores of young men and women. It is almost unnecessary to say that no form of life is mere attractive in an aquarium than fish. Most fish in captivity become quite tame. The little fellow mentioned above would come to meet the one who fed him; he would also play by the hour with his image in the glass wall of the aquarium. Should you decide upon fish, see that you give them plenty of shade. Feed them regularly and keep their aquarium scrupulously clean. Fish food may be purchased at any florists, and should be fed to the fish in small quantity once a day. Begin, at any rate, by feeding a little. If this is all used add a little more. Better be on the side of giving too little at first than too much.

Are you also interested in the beautiful shell of the pond-snail? You will fish some of these up with other pond-life. Feed them on lettuce and cabbage leaves. Should pond-scum gather, put in more snails and they will soon keep the scum in check. Tadpoles, too, are most interesting. Your only difficulty will be to keep them from climbing out of the tank when they have developed legs and arms and feel like using them. A glass plate used as a cover for the aquarium will keep all secure. Have you seen the black, shiny beetle that whirls round and round on the surface of the water? This is the "whirligig" beetle. Find out what he has to tell you. Then there are the predaceous diver, Fig. 31, the water-boatmen and other insect-life of a most valuable character. The young of the diver are known as water-tigers, and they are all their name suggests. There may be and there certainly is a charm to a sportsman's life, for the sportsman never knows just

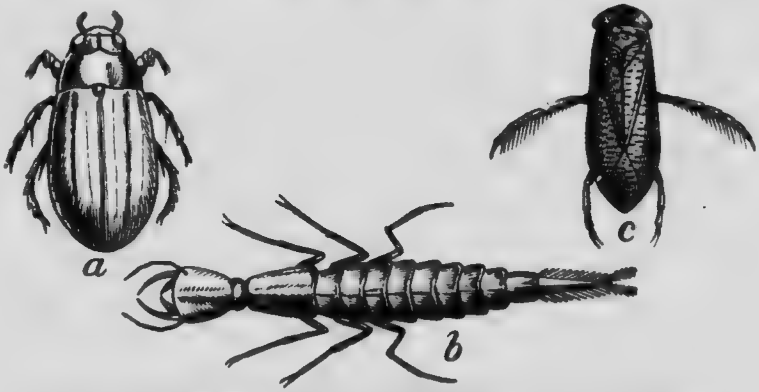


FIG. 31.—(*a*) The predaceous Diver. (*b*) The Water-tiger. (*c*) The Boatman.

what is going to "get up." There is just such a charm attending the hunting of aquarium specimens, for the collector never knows what form of life he is going to "fish up" next.

It is not the purpose of this chapter to enumerate the many characteristics of the lives of the creatures usually studied in the school aquarium. No one ever grows observant by depending too closely upon what others have said in the books. The aquarium brings the animal-life of the ponds and creeks where it may be easily studied, and where it may arouse a healthy curiosity to continue the study in the open air by nature's own aquarium. Nothing can take away the pleasure that comes from finding out the causes of things for yourself. Failures there may be, but failures should not discourage. Failure should only make us the more determined to succeed. Imitate nature. Keep the right balance between the plants and the animals. See that sufficient oxygen is in solution in the water. Do not overstock. Whatever is neglected let it not be cleanliness.

Questions.

1. Give an account of your work with a school aquarium. 2. What pond-life have you studied in natural ponds? 3. Why is it well to have plenty of water-surface to the aquarium? 4. What is the relation of animal and plant life in the water?

THE FROG.

Classification.—The frog is a member of a class of back-boned animals known as the *Batrachia*, or *Amphibia*, a life-group lying between the fishes on the one hand and the reptilian world on the other. Other members of this group are the toad, the salamander, and the mud-puppy; all of which are more or less common to the Red River valley.

Frogs are found everywhere, with the exception of the Arctic lands of eternal frost. Their main range may therefore be thought of as covering the length and breadth of the torrid and temperate zones or earth belts. The life-story of the frog is one of very great interest, and the literature dealing with the frog is of remarkable extent. Perhaps no animal, with the exception of man, has been the subject of so many scientific investigations. An animal, therefore, so easily procured and so interesting to students of science should surely be a subject of general interest and worthy of a prominent place on even a course in elementary biology.

The Aquatic Home.—The amphibia as a rule are more or less aquatic in habit, a feature which no doubt suggested the class name. Few of the amphibia can stand a long, dry season, and nearly all make for the ponds and water-courses to lay their eggs.

The home of the common frog is usually in or near the water. In wet or in damp weather, however, frogs have been known to wander for a considerable distance from the shelter of the friendly pond. This close association of the frog with the water may be readily explained when one has made some study of this animal's nature and needs. The frog is a slow-breathing animal, how slow the student may easily discover for himself. But why is the frog slow-breathing? Rapidity of respiration depends very largely upon the degree of activity of an animal. Should you call a frog an active animal? Have you ever made a note of the length of time a frog may sit without making any effort to change his position? The frog's lungs, moreover, are not nearly so perfect as the human lungs. In fact, the frog does not depend upon his lungs entirely for the oxygen needed. The frog's skin is something more than a mere covering. It is an organ of respiration, and it discharges its breathing function best when it is kept moist. Hence the necessity of keeping in touch with the water. Should the frog, therefore, go any distance away from the pond, he must choose where he goes, and we need not be surprised to find him in the damp grass, or within easy reach of the friendly water into which he can now and again take a plunge.

Another reason why the frog remains so closely attached to his pond is seen when one begins to have some idea of the frog's numerous enemies. It needs no great experience to have observed the splash after splash that heralds the approach of some strange animal to the frog-pond. What is the meaning of all this? It surely signifies more than the fact that sundry frogs which had gone ashore for a change had been frightened back into the pond. May not the splash have been a warning to other frogs on land, and also a warning to those in the water? At any rate, here is a fact that is worth trying to solve. Should any student have the good fortune to spend some time on this matter, let him note the behaviour of the frogs. Did those which jumped into the water act as if they were badly frightened? Did they seek the deepest holes in the pond and stir up as much of the pond-bottom as possible in order to conceal their whereabouts? Did they swim far out so as to make sure that a safe distance was placed between them and the source of danger? Did the frogs, on entering the water, take a few strokes under water, and afterwards come to the surface to make observation? Was any use made of the stones, weeds and sticks of the pond in this connection. If the pond was in full chorus, how long did the music last after the first splash was made? For these and other reasons frogs must keep in close touch with the sheltering waters.

Food.—We may as well admit at once that hunger has played a most powerful part in the drama of the world's life. We may also acquiesce in the fact that the struggle for the daily bread on the part of every living thing has often been a very severe struggle. Food is the greatest need of all living things, and the frog is no exception to this rule. But what does a frog eat? No answer is quite so satisfying as the answer which grows out of actual experience. Look at the frog's mouth if you wish to know how he feeds. For the rest make careful observation and the frog's bill of fare will gradually grow.

What any animal eats is a much more important question than it at first appears. If one only knew the food habits of the frog, for instance, one could then easily place it among those animals, either beneficial or injurious to man. The food habits of an animal are the only evidence worth considering in this matter of ascertaining the animal's real worth.

The food of frogs consists of insects, in fact, of almost any kind of animal small enough to be caught and swallowed. Such a statement is pretty general, and is given only as a working basis. No student of *animal biology* should be satisfied with anything short of ascertaining what particular kinds of food frogs show a fondness for. Test the frog with various foods and make a record of the things frogs have actually eaten. Only in this way can correct statements be made in a field that has been very meagerly explored. Were two hundred or more students really interested enough in this important question, such a mass of evidence could be gathered that generalizations of immense value to the country could be made, and human progress materially aided.

Frogs have been known to devour several large earthworms at one meal. Bees and wasps are also eaten and apparently relished. What about the stings? Has the frog preferences? Does a frog eat almost anything that may come his way? Is he particular about eating the products of his own hunting, or will he take what is given him just as well? Does he prefer living things to dead things? Would you say that his senses of taste and smell are acute?

Make a study now of how the frog seizes his food. We have already suggested a study of the frog's mouth, so begin by opening his mouth and examining his teeth and tongue. Do not be afraid of attempting this. There is not the slightest danger so far as you yourself are concerned. But do it gently. You will find that the frog's tongue is attached just inside the mouth opening, and its free end, when the mouth is closed, extends backward toward the gullet. In other words, the tip of the frog's tongue points down his throat. "What a big mouth and what a strange tongue," you may say; but wait a bit, "handsome is that handsome does." When you see how well these are adapted to securing the ends for which they are intended, you will learn that there is such a thing as beauty of adaptation. Place a frog in a wire box containing some moist sand. Catch a dozen or more flies and put them in the box. Watch closely and you will see the frog's mouth open, the tongue dart forward, and the probable disappearance of one of the flies. How does the frog do this so quickly? Is the large mouth a help or a hindrance? The end of the tongue has a sticky substance on it. Of what value is this in the fly catching? Would you say that the frog was guided more by the motion of his prey than by its color? Would you say that the frog was a night or a day feeder? Notice the frog's attitude when catching flies. Point out some of the advantages of this? Does a frog drink? How? Where are a frog's teeth situated? On which jaw? Notice the way the teeth point. Of what value is this? Are their any teeth on the opposite jaw? Where?

Movement.—Observe now the general movements of the frog. A frog can leap and swim. In leaping, which legs play the chief part? In what ways are these legs adapted for leaping? Do you see any signs of readiness to jump at the least sign of danger? What are these signs? In leaping, does the frog always jump in the direction his head is looking previous to the leap, or may the flight take a curve? Measure the length of a frog's leap. What is the frog's favorite resting posture? What makes the hump on his back? Can the frog walk and run? If placed on its back, how does he right himself? How does a frog swim? What do the hind-legs do in this act? What do the fore-legs do? Are the frog's movements in swimming like those noticed in leaping? Watch the way the frog takes his hind-legs up? Note the backward push and see what its result is. Watch the toes. Can you show how all these movements aid in propelling the frog through the water? Where are the fore-limbs kept during the swimming? What strokes are taken and for what purpose? Try to find out how the frog dives and rises. Notice his posture while resting on the water-surface. Make out all you can favorable to a rapid disappearance should there be any cause for this. What have you to say regarding the frog's buoyancy? Has he any way of increasing or decreasing this? How do you account for the air-bubbles that usually rise to the surface when a frog has taken a sudden dive?

Enemies.—Make a study of the natural enemies of the frog. Are any of these in the water? What are they? Are any of his enemies on the land? Are any in the air? Make a list of all of these. In resisting and in evading his enemies the frog must make use of various weapons, some of which might be considered weak in comparison to the teeth and claws of other animals. At the same time it will be found that these simple weapons are very valuable life-preservers. Among these we may mention the power to puff or swell the body, a condition that would make the swallowing of the frog by a snake a very difficult process; ability to remain perfectly motionless while danger is near; life in or near bodies of water; ability to change the body-color somewhat, etc. All of these and others the student may readily discover, and should study them as means to ends, the end being the preservation of the life of the frog.

Hibernation.—Where do frogs spend the winter months? Here is a field for original investigation. One should expect a water-loving animal to make its winter home in the water, but this is not a sufficient study of the matter. No doubt frogs take to the waters of the deeper ponds and to the rivers, and probably bury themselves in the mud bottoms. No doubt rivers, if they could speak, could tell us much regarding frogs during the winter season. But this is not very satisfactory. We must have direct evidence. When shall we prepare for taking such evidence? Let students watch for signs of frog-life in the fall of the year. May be a small, shallow, water-hole is found to be literally filled with frogs. Such a hole was observed near the Assiniboine at Brandon. What did it mean? It seemed to indicate a preparation for the winter season, for some of the frogs had gone down a couple of feet in the soft mud. Granting all this, how is it possible for a frog to breathe in such a place? Frogs are not rapid breathers. Add to this the fact that in the winter-season all that is looked for on the part of the frog is enough life to carry it to the spring season. The frog goes into hibernation after a successful food-season. He has, therefore, a stock of food stored up in his body for the lean months of the winter. When properly established at the bottom of the pond or the river, the frog lies in what may be considered a dormant condition until the coming of the spring. In other words, life at this season seems to have run down; very little energy is expended and little food is used; only a small amount of oxygen is needed, and this the skin is able to secure from the water.

The frog belongs to the cold-blooded animals. To be more exact, the temperature of a frog's body is much lower than that of the human body. In the case of the majority of warm-blooded animals the temperature remains constant under summer and winter conditions. With cold-blooded animals it is different; and their temperature rises and falls with that of their environment. This statement, of course, is not absolutely correct, for even the so-called cold-blooded animals have the means of varying their temperature. Evaporation from the surface of the body of a frog is a cooling process; and the life-processes of even a dormant frog are attended by some slight rise of temperature. Frogs, however, have little power of withstanding severe winter cold, for the reason that they have no means of keeping up a high bodily temperature, or a temperature much above their surroundings. On the other hand, frogs can withstand a reduction of bodily temperature much below the point which would be fatal to a warm-blooded animal. It is said that frogs may be frozen in ice for a short time and afterward recover, if the thawing-out process has been gradually done. If the tissues have become entirely frozen the probability is that the animal will not recover.

External Anatomy.—In our treatment of the frog so far we have made no general study of the external anatomy. In other words, we have not made a sufficient study of the animal's body as a whole. Individual acts have been studied, but such acts can not be fully interpreted apart from a consideration of the whole bodily mechanism.

Note, therefore, the flattened, more or less triangular head set on a trunk with no apparent connecting neck. The head carries the eyes, ears, nostrils and mouth. Examine each of these organs in turn with the view of understanding not only their appearance and situation, but more especially their fitness for the work of the frog. Do not forget that in all this study you are endeavoring to appreciate how well a frog is fitted to be a frog.

What do you make of the protruding eyes? Open the frog's mouth that you may see how important a place the eyes occupy, and also why there is so much mobility attached to frogs' eyes. Try to discover the value of this to the frog. What is the shape of the pupil of a frog's eye? Does the pupil enlarge and contract? Remove the crystalline lens from the eye of a dead frog should you have the opportunity so to do, and preserve this lens. Try with its help to determine if the frog is long or short sighted. Note the frog's habits. Do any of these throw light upon the matter of short sight? In what particulars? How many eyelids has a frog's eye? How much movement has the lower lid? Observe a frog's eye when the frog closes it. What two features are thus revealed? Watch a hen shut her eyes and compare the results. Describe the appearance of a frog's ears. What you see on the outside is the eardrum. Look for the opening of the nose just a little above the frog's snout. These openings are guarded by, what we might call, valves, and these valves close and open as the animal breathes. Pass a bristle carefully through one of the nostrils. You will find that there is communication with the mouth. Watch the frog breathing. In attending to this make a note of any mouth-movements and movements of the body as well. What have you discovered? If you were to keep a frog's mouth open for a time you would suffocate him. In breathing the frog first fills the mouth cavity with air. You evidently saw how the floor of the mouth bulged out. The air courses through the *nares* (nostrils) into the mouth. The frog then presses the edge of the upper lip as it were over these openings, and by keeping the mouth closed forces the air from the mouth into the lungs. Why cannot a frog breathe as we breathe? To answer this question we must acquaint ourselves with the skeleton of the frog (Fig. 32). A real skeleton may

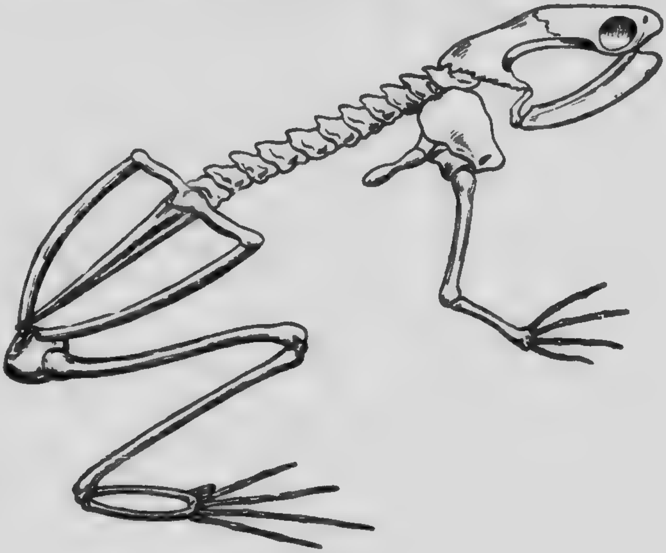


FIG. 32.

be obtained by placing a dead frog in an ant-hill. In a few days the bones will be picked clean, and the skeleton may then be studied. Note that a frog has no ribs, at least not well defined ribs. How does this help you to answer the question of breathing? Do you not see the advantage of forcing the air, under these circumstances, into the lungs? How is the air expelled?

Make a study now of the frog's appendages. Look for the tail. Has the frog a tail? Has a tadpole? Compare the frog's fore-arm with the human arm. Does the comparison hold in the case of the frog's hind-legs? Have you been able to make out the arm, fore-arm and hand? Point out the resemblances and differences to a human arm. The divisions of the leg are the *thigh*, shank or *crus*, and the foot or *pes*. Count the fingers and the toes. Note the hand of the male in the breeding season. Are the fingers of the same length? Have fingers and toes nails? Has a frog a fist? Are the front feet webbed? How about the hind feet? Find knee and elbow.

Notice the general shape of the frog's body when swimming and when resting. Account now for the hump. Can you see any reason for such a strange development of the pelvic bones (hip-bones)? Has the frog a hair covering, or any other covering besides the skin? Catch the skin in the fingers, and observe how loose it seems. Notice its wonderful moistness and its color. Compare the color of several frogs and make some statement regarding what you have noticed. Be on the watch for the manner by which frogs remove the old skin. No one seems to be very definite on this point.

Finally, study the color-changes in the frog, but bear in mind that no frog possesses the power of adapting himself to all the changes of his environment. Frogs possess the power of adjusting themselves to the predominant colors, namely, the color of the vegetation, and some shade of gray or brown, the usual color of the bark of trees and the soil. The cause of such color-changing is too complex to grasp very readily. Suffice it to say that it is largely due to certain pigments in the skin, and that these pigments respond to the predominant color of the surroundings.

The Frog in the Springtime.—We come now to a consideration of the most interesting part of frog life, the beginning. The frog commences life as an egg. To find the eggs one must visit the stagnant waters that are common everywhere in the early summer or late spring. The time for finding the eggs depends, of course, on the season. One is guided to the breeding place of frogs by their call or song. Frogs have voices and frogs will give you an exhibition of the character of their voice if you simply stroke their sides. Frog choirs are composed in the main of male voices, and different frogs, like different people, have dissimilar voices. The variety is just as great as among human voices. How does a frog sing? Not by opening its mouth, for it is said that a frog can sing under the water. To know just what is done is not a matter of books. Go to the pond at the height of the frog music season. Approach very quietly, for frogs have good ears. When near the edge of the pond remain motionless and keep your eyes on the alert.

The sound-making organs of the frog are located in the larynx. Where are yours situated and how do you make a noise? Open the frog's mouth and make a note of the two openings leading into the body cavity. The centre opening leads to the stomach and the slit-like opening leads to the lungs. Back of the latter the larynx is placed. Study Fig. 33.

In the springtime frogs come out of their places of hibernation and make at once for the quieter waters of swamps and sloughs for the purpose of breeding. After gaining the breeding grounds they regale the neighborhood with their noisy choruses. In your consideration of sound in frogs endeavor to determine the purpose of so much sound being given to the spring season. Are the frogs like the birds in this particular? Is this music a feature of frog courtship do you think? Or is the music just as forcible in the late summer, only we have grown so familiar with it, that it ceases to take our attention?

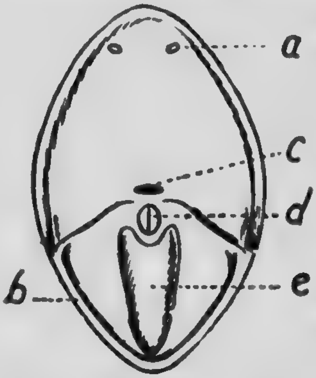


FIG. 33.—(*a*) Nares. (*b*) Lower jaw. (*c*) Opening leading to stomach. (*d*) Glottis. (*e*) Tongue.

The Eggs.—After having obtained evidence of the presence of the frogs in the spring, watch for signs of the egg masses on the surface of the water. Should you see an amber-colored mass on the water, wade out to where it is situated. Should you get wet, the discovery of the eggs will be a compensation. Study the mass. Note the color of the eggs and the jelly-like substance in which they are embedded. Does the mass represent the eggs of just one frog, or does it show the combined work of several frogs? Does it remind you of tapioca pudding? As the mass is many times the size of a frog, you will think at first that it represents the eggs of a group of frogs. When the eggs were thrown out on the water surface they were quite small. But the material surrounding the eggs has the property of absorbing a considerable quantity of water which causes the mass to swell and thus to render it more buoyant in the water. Make observations bearing on the attention given by the frogs to their eggs. Is the frog mother as good a mother as the domestic hen? What hatches the eggs? May not the substance of the mass and the color of the same aid in collecting the heat of the sun and retaining it? Will frost destroy the eggs?

While it is a good thing to observe the natural hatching of the eggs, it is well also to place a dozen or so of eggs in the aquarium so that every incident attending the hatching may be observed. If the eggs are placed in a sealer containing some of the pond water, all the phases of the hatching may be readily noted. How long a time does the hatching take? Was the process retarded or was it helped by the cold weather? When did you first see signs of life in the eggs; How soon after this did the tadpoles emerge? How did the tadpoles behave after leaving the eggs? Did the tadpoles stay in the vicinity of the egg-mass for a few days, or did they move away from it altogether? If the former, how did you account for it? If the latter, can you give any reason?

The Tadpole.—Examine the young tadpoles with a small hand lens. Do they look like a frog? In what way do they resemble a fish? Can you find their gills? Have they a mouth and eyes? How do they move about in the water? What do they feed upon? Look at the pond if you wish an answer to this question. Do you know why the sticks and stones on the bottom of ponds are so slippery? It is because of their being covered with a slimy, vegetable growth; and this material is the natural food of young frog and toad tadpoles. Procure some of this and feed it to the young of the aquarium. As the tadpoles grow older and larger, try other foods and compare their general condition from day to day with tadpoles left entirely to the care of mother nature. There is bound to be some difference; how do you account for this?

To raise tadpoles successfully it is a good thing to take an earthen milk-pan and place it in the ground. Into the pan put some of the pond earth, making one side deeper, so that when the pond or rain-water is added there will be both deep and shallow water. This pond may be shaded like a natural pond by planting bits of willow about the edge so that the rays of the sun may not be too much for the tadpoles.

Observe the movements of the tadpoles. Try to ascertain just how movement is effected. Later, note the growth of the legs. Which appear first? The fore-legs were probably just as far advanced, but the gill-covers concealed them from view. Note also that the tadpole now makes frequent excursions to the surface of the water. In fact, the tadpole is developing his lungs, but he needs the gills for some time yet. Note also the change coming over the tadpole's tail. The white cells of the blood are gradually removing the material of the tail and using it to build up other portions of the frog economy.

When the legs are well developed, and the tail has been reduced to a mere stub, the little tadpoles like to put their snouts out of the water, and sometimes to crawl a few inches up the side of the pond. They now look like a full grown frog in all but size. Should one chance to visit the neighboring frog ponds about the end of June or during the early part of July, he will see a great many small hoppers along the edge, and should a warm rain come on, he would be no doubt surprised at the great number of frogs that seem everywhere. This is a common experience, but many good people explain it by saying that the frogs came down in the rain. Students who have studied frog-life know better. Frogs are necessarily cautious creatures and stay out of the hot sun in the damp, cool places that everywhere abound. What wonder is it then that these should come into the openings when all the danger of a hot sun were removed for a time.

Finally, as you study the frog from day to day, and from week to week, endeavor to come to some conclusion as to his actual worth so far as man is concerned. Should you discover a good trait, give the frog credit for possessing this feature. Should a bad feature be found set this down on the opposite side of the account. Only by so doing can you arrive at any just conclusion regarding the value of this much abused animal.

The Warty Toad.– As you study the frog a kindred animal will come across your path. Should you live in a town you will probably see this little animal in the early evening, hopping toward some friendly electric light, where thousands of flying things love to gather. The warty toad, for it is none other, has an eye to business. He is not the last animal to take advantage of the conveniences of modern life. Watch him take his stand, or rather his station under the post and try to discover what he is doing. Should you live in the country the toad will probably make your acquaintance in the garden or on the doorstep. Follow him for a short time on his evening round.

Toads are nocturnal. Toads are more of the land than they are of the water. Toads are fond of the closely cropped lawns, for their movements are not so impeded as they would otherwise be were the grass long. Toads have not the same color as frogs. Observe if color here is an aid to concealment. To answer this just start some fine summer or early fall evening to see how many toads you can discover in the space of an hour. This experience will help you to understand the value of the two qualities of color and quietness. Perhaps you may chance to come across a toad in the day time. If so, make a note of the way his color harmonizes with that of his surroundings. Toads are also warty, and this has been a source of much discomfort to people in general. People are all too ready to jump at conclusions, and have reasoned that because warts on the hands resemble warts on a toad, therefore it is not safe to handle toads. Now the warts on the toad are really glands which emit a milky juice of a very irritating character should the toad be handled roughly. Watch the antics of a young dog after he has made the acquaintance of a toad. He will not likely repeat the experiment, for the liquid emitted by the warts has got on the delicate skin of his mouth and has caused considerable irritation. Do you blame the toad for using this means of defence? Study the matter of getting warts from handling toads. Sift every experience to the bottom, and see whether your conclusion will agree with the conclusion given above.

Make a study of the toad as you did in case of the frog. You will find many resemblances and many differences. You will find differences in hands, feet and eyes. Look closely at a toad's eye. It is one of the most beautiful objects in the whole, wide world. Indeed, a toad is not an ugly animal at all when you come to know it better.

Watch the toad hopping about the garden. He is busily engaged in gathering his food. What does he eat? Place a toad in a box and feed him on various insects. This will help you to understand what an enormous appetite a toad has; what a variety of insect-food he will destroy; how he takes his food, and of what great service he is to the garden. You will discover that he wants to do his own catching, and that he is anxious to get better acquainted with you. Indeed, a toad may be easily tamed. He has not taken up his quarters near human habitations without being in a measure domesticated. Give him a chance of becoming better acquainted. What is more to the point, give yourself a chance to get acquainted with the toad, for you do not know him as well as he deserves.

The beginning of toad-life parallels that of frog-life. The eggs, however, are deposited in long ribbons or necklaces about weeds and sticks. Should you find any of these repeat the school experiment, and compare the toad tadpoles with their frog relatives.

Where does the toad pass the winter? Not at the bottom of a pond buried up in the mud, but burrowed in the loose sandy soil, or beneath some rubbish pile far enough away from the reach of the severe frost. How can a toad burrow? Well, place a toad in a box containing a few inches of soil and watch how quickly he can get out of sight.

The toad has many enemies which prey upon him. Unfortunately the small boy plays altogether too prominent a part in injuring an animal he does not know the value of. The cry of the toad at the spawning time is usually the signal for this same small boy to make his way toward the pond where he may test his skill at stone-throwing. Why should there not be as stringent legislation against the destruction of so useful an animal as there is against the destruction of our insectivorous birds? If boys and girls would only try to throw their little prejudices aside and study the animal, we should expect such an education of public sentiment in favor of the toad that all the libels ever invented would be set aside, and the toad would be looked upon as one of nature's very best agencies for sure human good.

Questions.

1. Make a comparison of the frog and the toad. 2. Discuss the probability of finding toads and frogs in solid rock. 3. What has the frog in common with other animals that jump well? 4. Look for pulse beats near the rear of the frog's body. 5. Make drawings of a frog in the sitting and also in the swimming positions. 6. Compare the colors and markings of the upper and lower surfaces of the frog. 7. How can the frog breathe when under water? 8. Have you ever seen signs of a temper in the frog? 9. What makes the frog hump-backed? Is a toad hump-backed? 10. Is a tadpole a fish? 11. Find out what you can regarding the salamander and the mud-puppy. 12. Which is the better friend of man, the toad or the frog? 13. Does a bear's heart beat more slowly, his body temperature drop, and his breathing become slower during the period of hibernation?

THE BIRD.

What is a Bird?—Is a bird simply a warm-blooded, egg-laying, feathered animal whose fore-limbs have been modified to form wings, and whose jaws are encased in horn to form a beak? The chain connecting the modern bird with the remote past is here and there broken. Still fragments of evidence exist, and these if properly pieced together, seem to give some little account of the descent of the bird. From this evidence we may gather that what is now termed a bird has reached its present form by slow changes from some other form of life resembling what is now known as reptilian life. Our reason for so concluding is based upon the fact that the bird, more than any other animal, shares many characteristics in common with this class; probably because both may have come from a more primitive stock. We must not, however, read too much into this; we must not think for a moment that a lizard, for example, is of the same rank as a bird. The bird fills a much higher place in the scale of life than is filled by any member of the world of reptiles. Exactly how these changes have come about, no one can say. This much, however, is worth mentioning. No two members of any family are perfectly alike; no son or daughter is the exact counterpart of father or mother. To put this in another way, we may say that all the individuals composing the population of any city, town, village or rural locality, do not agree, for instance, in the matters of weight, height, color of hair and eyes, etc. If an average were struck in any one of these particulars, a part of the population would be above and the remainder would be below this average. In other words, there seems to be a tendency to vary, and this tendency is the essence of the theory which tries to answer the question, "What is a bird?"

Man, long ago, observed the working of this law and turned his observations to account in animal and in plant breeding. A similar process of selective breeding appears to be going on in the whole field of nature. Anyone acquainted with the seemingly marvellous results of Luther Burbank's work among the plants of California will readily understand what is here meant. But why a reptilian ancestor? Because a study of the fossil bird-forms found here and there in the rocks is the only source we have of the history of the life of the remote past, and among these bird-forms are evidences of birds possessing sharp teeth, a tail of many vertebræ each bearing a pair of large feathers, claws on the hand, and a number of other features distinctly reptilian in character. Look, for example, at the scales on a bird's foot and say whether this points to a kinship with an animal of the cat kind or to one of some other class.

Feathers.—The special feature of birds is seen in their power of flight. Birds are adapted for rapid transit through the air. To enable them to fly, feathers are necessary, and birds, and birds alone, produce feathers. But what is a feather? If this were easily answered more of us would have studied the mechanism of a feather long ago and probably the air would have been conquered by man in much the same way that the sea has been brought under his control. A feather is not a single, simple thing. A feather is a structure admirably adapted to the needs of a bird and consequently of a most complicated make-up, because the power of flight is a power the world is only beginning to understand in a small way. Did it ever strike you how ungraceful the body of a bird becomes when stripped of its feathers? Have you ever felt the delicate skin in which feathers grow? A newly-hatched sparrow appears to be entirely naked. A closer examination would probably reveal tufts of down in irregular patches over the bird's body. On still closer examination you would discover what appear to be patches of a pimply nature here and there. The down is but a temporary covering. The pimples mentioned are anchored in the *dermis* or deeper layer of the skin. As they grow they push upward into the outer *epidermis* and spread out below in the dermis. The upward extension splits lengthwise into a number of folds which gradually dry apart and form the silky thing we call *down*. At the base of the pimple is a group of cells which grow but little while the down is in use. When, however, the bird is ready for its permanent feathers, these cells begin to develop, and a second column is the result. This column pushes the down ahead of it, and enters the air where it expands into the well-known feather.

When feathers appear above the skin they look like a lot of stubby, bluish rods. Each feather is enclosed in a horny sheath, which dries up eventually, and causes the feather to unfold. If you have been observant in these matters you no doubt have wondered at the rapid appearance of the feathers from these *quills*. You may also have noticed that very young chicks are covered with down, while sparrows of the same age are almost naked. But have you ever connected these facts with the helplessness of the young birds?

Do you see any reason why a crow, for example, should care for its nestlings so long, while such birds as prairie chickens leave the nest shortly after the young are hatched?

Structure of a Feather.—Having seen how feathers are produced, let us now examine a fully-formed feather. A wing or tail feather of a crow, pigeon or even sparrow will answer our purpose very well. If none of these can be secured, perhaps a feather from the domestic hen may be had. If we look closely at the make-up of a feather we shall find that it is composed of feathers within feathers. Every large feather consists of an *axis*, divided into a hollow portion, called the *quill* or *barrel*, and an upper, spongy, though firm portion called the *rachis* or *shaft* which bears the *vane* or *web*, in other words, the expanded portion of the feather. The vane consists of parallel rows of smaller feathers, the *barbs*, which are linked to each other by still smaller feathers, the *barbules*, which in turn may be joined to one another by a series of hooks and notches. Fig. 34 will give one a fair idea of the nature of a barbule and its parts, and the student will understand now why the web is able to offer so much resistance to the air, or to any force trying to separate the barbs. These hooks, or *barbicels*, work into opposite series of grooves, and are so firmly interlocked that air has some difficulty in forcing its way through the web of the feather.

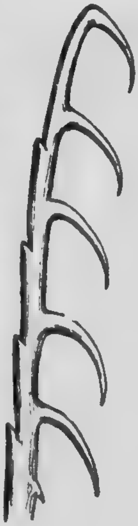


FIG. 34.

At the lower end of the feather, fluffy barbules may be seen. Such portions are useless for flight, but most useful for keeping the body warm. How so? In the case of the duck many feathers are of this nature, a circumstance that may account for the success this bird has against the wet. Notice that one line of barbs, those along the inner curve of the feather, are a little longer than those opposite. The longer side is overlapped by the feathers above, an arrangement which makes of a feather a much stronger mechanism for beating the air. Does this interfere with the lifting of the wing? In other words, is the air prevented from passing through the feathers as the wing is being elevated? Notice, too, that the axis is more prominent below than it is above, and that the barbs and the upper surface of the axis are in about the same plane, features that point to a much easier flight through the air. Test a feather by bending it from tip to barrel. Release the feather and notice the amount of elasticity in it. Of what value is this?

We have already mentioned that the young bird shows feathery patches; that the whole body, in other words, is not equally feather-covered. Part the feathers of a sparrow's breast; a bare area may be seen. It would seem that the bird has feathers just where feathers may be of use, and it may not be a useless thing for the student to find out the most important feather-areas or lines.

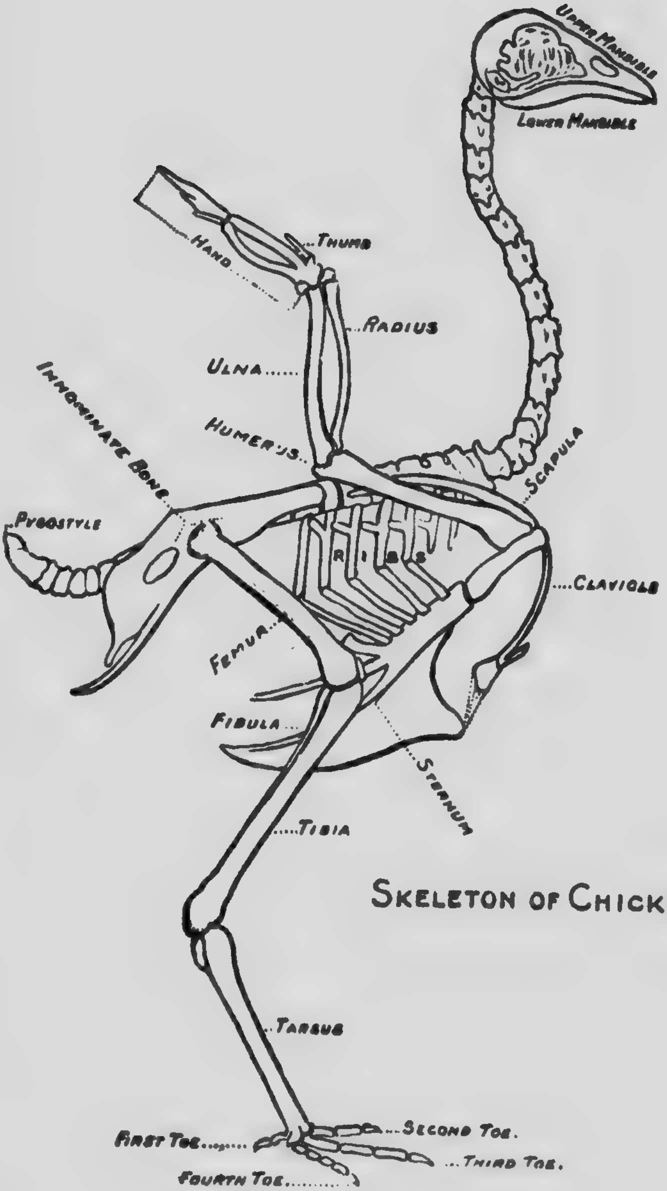
Moulting.—The body of a bird is constantly undergoing waste and repair, and feathers come under this law. Every person has seen birds dropping their feathers. This is not unusual, for cows shed their hair, and grasshoppers rid themselves of their coats when these get too uncomfortable for their owners. Birds *moult* at stated periods, and moulting is a critical period for such birds as depend upon strong flight in order to escape from their many enemies. Feathers fall out, or moult, at least once a year. At what season does this usually take place and why? Should a sparrow shed all or most of its plumage within a few days, what a helpless creature it would be. Could such a sparrow survive in the midst of so many dangers? Nature has provided for this difficulty in her management of the great flight feathers. These moult by pairs, the pair first to go being the pair that can be spared most easily. Do these feathers belong to the inner or to the outer part of the wing? The next feather on each wing drops out after the first pair have been replaced. In this way a crippled flight is prevented, but there are many exceptions to this rule.

Ornamentation.—Feathers are for more than flight and covering. Feathers are also for ornament. Make a note of the mid-winter dress of the sparrow. As the spring advances observe how the cravat of the male bird gradually darkens, and try to account for the change. Birds seem to understand the meaning of gay colors and it will be well for the student to take into consideration the part that color plays in bird-life generally. Before the Bob'olink leaves for the south the male bird takes on a very sombre dress, a dress quite the opposite of his flashy summer black and white. Examine whether color plays any considerable part in concealing birds from their enemies, and also why the male bird is more gaily plumed than his mate? Examine a number of feathers to determine whether the color is due to some pigment in the feathers or to the feather-substance playing the part of a prism. This field is practically unexplored.

Every student has, therefore, a possibility of becoming a second Columbus, for no one knows exactly the full meaning of color in birds, marvellous as those colors appear.

The Skeleton.—Examining now the general form of the bird, note that it is somewhat the shape of a double cone, a form admirably suited to the easy cleavage of the air. In studying the form of the bird, one should have the framework at hand so that it can be frequently referred to. Place a dead sparrow in a box and put the box in an ant-hill. In a few days the small skeleton will be ready for use. Study also the following cut, but do not place entire dependence upon it. Take advantage of the opportunities of even a chicken dinner. Such a study of anatomy will in no wise interfere with the enjoyment of the dinner.

In studying the framework of the bird you will find a very great tendency on the part of the bones to fuse or mass together. The skull is a box of many bones. The thorax, or body proper is another box. The hand is changed by the fusion of bones. The tail-bones have been greatly modified and the great mass forming the rear portion of the body shows a union of several bones. In a few words, the skeleton of a bird consists of a long chain of bones with the brain-box at one end and a stumpy tail at the other. Near the centre the out-curving ribs surround the vital organs of the body, and with the breast-bone form a very secure chamber. How is it possible for a bird to be comfortable with such a lot of queer shaped bones? Looking more closely, it will be seen that while every bone may be different from



SKELETON OF CHICKEN.

Fig. 35

those it fits into, every bone is nevertheless admirably suited to such connection.

Head and Neck.—The bones of the head are too difficult for us at this time. We shall simply refer to the beak by asking students to observe its wonderful flexibility and its adaptability to such movements as —picking up small stones and seeds, preening its feathers, assisting in its battles, weaving beautiful nests, etc. What the fingers are to the human being, the bird's beak is to the bird. How many bones are there in a fowl's neck? In a sparrow's neck? In the human neck? How much motion has the human head? How much the head of a bird? How is this difference explained? Notice the double curve of a bird's neck. How does this affect the position of the head? How does it affect the general grace of the bird-form?

Thorax.—Coming to the thorax, make a note of the barred structure of the ribs. What do you suppose is the purpose of this latticework? Note the slant of the ribs of a chicken and compare with the human ribs. The sternum or breast-bone has a projection beneath called the *keel*. The size of the keel indicates the bird's flying power. The keel enables the bird to cleave the air more readily and forms an admirable anchorage for the great flight muscles of the breast. At the point of attachment of the wings with the body there are to be found a trio of bones. These bones are the *scapula*, or shoulder-blade; the *coracoid*, a stout bone joined to the shoulder-blade and reaching downward and backward to the breast-bone. This bone is very strongly developed in birds and becomes the pivot upon which the bird's wing turns. The third bone is called the *clavicle*, wish-bone, or merrythought. It is usually V-shaped, the two collar-bones being joined at their tips. What is the function of the human collar-bone? What is the function of the bird's merrythought? To retain such a bone, a bird must continue to fly.

The shoulder-girdle, or pectoral girdle, just described, points to an arm of some kind, and birds have arms or wings. As the flight of birds meant changes in the bones of the arm, we need not be surprised to find a considerable difference between the arm and hand-bones of a bird and the corresponding bones of the human arm and hand. The arm-bone of the bird is relatively shorter and heavier than the bone of the human arm. Find the bird's elbow and compare the *ulna* and *radius* of the bird with similar bones of the human arm. As a bird would be at a disadvantage with a weak wrist, we should expect some difference here, and we shall not be disappointed. There are eight bones in the human wrist, permitting the most graceful movements of the hand. In the bird these are all missing with the exception of two bones. Would the outward portion of a bird's wing be very serviceable were the wrist to turn at every downward stroke? Strength and stiffness are necessary at this point and these are secured by diminishing the number of wrist-bones. The bird's hand has also features common to the human hand. The thumb with its two bones is easily seen in a chicken. The next finger has three bones, and the remaining finger one bone. The fourth and fifth fingers are wanting. The student should make a close examination of the framework of a bird's wing, and endeavor to make out the relation between these bones and the general function of the whole arm.

Legs.—Coming to the leg-bones, we find the leg anchored on the three great bones of the *pelvic* or thigh girdle. These we need not name, as the valuable feature for the student to grasp is the strong anchorage these give to the bird's legs. Being accustomed to locomotion on the land, the arrangement of the bones in a bird's leg are not so different from that of the human leg. There is the short thigh-bone or *femur.* The bird's knee is therefore likely to escape attention, for it is concealed by the feathers and also by the body of the bird. The bones between the knee and the ankle are the *tibia,* or drum stick, and the *fibula,* a mere splinter of bone. The foot of a bird differs very much from the human foot, for the heel is several inches from the ground and the bird walks upon its toes. The large bone between the heel and the toes is called the *tarsus,* which is covered with scales, a feature suggesting, as we have said before, a reptilian ancestry. Think of our small toe as missing, the big toe turned backward and the heel lifted off the ground, and you will have a working idea of the make-up of the bird's foot. The hind-limbs in all birds are organized for locomotion. Birds can walk, run, hop or waddle on land. In some the foot is fitted for perching on trees and other supports capable of being grasped. Try to find out just how a hen clasps the roost. In some birds the leg becomes a paddle for swimming, a hand for catching, or a rake for scratching. Indeed, the hind-limb is often much more modified than is the flight-limb for reasons which are plain to see.

Tail.—Finally, examine the tail-bones, a small chain of very interesting bones. It is necessary for this part to be large and strong, as it has to do with the great feathers of the tail. To insure success in its function as a rudder, the tail must have sufficient freedom of motion, hence the separation of these bones from those forming the back of the bird.

Wing-feathers.—Having made a preliminary examination of the skeleton of the bird, let us now see how the great feathers are disposed. First we shall consider the feathers of the wing. That these are very important may be guessed from the consideration that they are the bird's chief organs of locomotion. Without feathers there would be no need of such a mechanism as a wing at all. Wing feathers are of several kinds; the flight-feathers proper, or long, stiff quills, collectively called *remiges, i.e.*, rowers; and the smaller and weaker feathers over-lapping them, and hence called *coverts.* These are the main divisions of the wing-feathers, if we omit the small bunch of *spurious quills* growing upon the bird's thumb and giving a finish, as it were, to the bird's wing.

The remiges or flight-feathers give the wing its general character. Together they form a highly elastic surface for striking the air. A short, rounded wing hints at a labored flight and a whirring sound. The long, pointed wing gives a noiseless, airy flight, a flight that may be prolonged and one accompanied by very deliberate wing-beats. Remiges are divided into three series or groups according as they grow on the hand, the fore-arm, or the arm, and this is one of the most valuable facts of bird study. These feather-groups get the names *primaries*, *secondaries* and *tertiaries*. The primaries are usually ten in number; the secondaries vary from six to forty or more, and they have also the feature of being fastened in the ulna. If the ulna of a bird be examined there will be seen a row of small points showing this attachment. The tertiaries are not very evident in most birds and need not be considered here.

Tail Feathers.—The next important series of feathers are those of the tail. Time was when birds flew about with long, bony tails. Now, the bones of the tail are few, usually nine in number, and so short that they do not project much beyond the ordinary plumage of the bird. The last bone, a bone much larger than the rest, bears the great tail feathers, which radiate from it like the arms of a fan. The whole bony and muscular tail is the well-known "pope's nose" of the Christmas turkey and the point to be noted is that—this is the *real* tail of the bird, the feathers being only appendages. The feathers of the tail are of two kinds, the *coverts* and the *rectrices* or rudders, because they seem to be used to guide the flight of the bird. The tail-coverts are the numerous and comparatively small feathers which appear above and below the rudder-feathers, and give these support and the tail completeness of form. The tail-feathers proper are usually twelve in number, but the length and character of these feathers and of the tail-feathers as a whole vary so much that a comparison is suggested in a study of the tail-feathers of the sparrow, the rooster, the robin and the peacock, or the turkey-gobbler.

Food.—Birds, like plants and animals generally, have two things and only two things to attend to, namely, to look after themselves and to look after their offspring. In caring for themselves birds must procure food, must have organs to prepare this food for the body, must be able to defend themselves against their natural enemies, and must have considerable powers of adaptation to environment. What has been said regarding bill, wings and feet may be considered in connection with the activities mentioned above. Should the food of one region fail, the bird has the means of reaching another locality more favorably situated, and this may be done in a very short period of time. In many birds, the common fowl for instance, the *gullet* or food tube leading from the mouth to the stomach is provided with a large, thin-walled bag, the *crop*. Into this a considerable quantity of food may be taken, to be digested later on. No digestion takes place in the crop, but the food is softened by being mixed with saliva. The crop, in fact, is a sort of storehouse for such birds as are likely to be much exposed to enemies. These birds can gather their food quickly and then retire to a secure spot to assimilate it. The grain devoured by pigeons and poultry, passes from the crop to the *gizzard*, a large, muscular organ of great thickness. The walls of the gizzard are armed with two very hard pads which rub against each other after the style of millstones, and this process of grinding is aided by the quantity of small stones swallowed by these birds. The crop and gizzard just described may be seen in place if the student will only take advantage of the next fowl that is being prepared for the dinner table.

Defence.—In defending itself from its enemies, and in its own private battles, the bird uses beak, wings and feet. Make careful note of the long spurs that adorn the feet of an old rooster. Watch two such birds fighting if you would know just how such weapons are used advantageously. Some birds depend upon their flight powers to carry them out of harm's way or to enable them to overcome their flying prey. Note, in the latter case, the terrific flight of some of our hawks. Note, also the part that color plays in concealing and in exposing the bird.

Adaptation.—As to adaptation, what has been seen in connection with beak, wings, feet, etc., are all adaptations. How is it that the domestic hen and the English sparrow are found in regions far away from their native homes? Man certainly has had a hand in this, and has made the life of the hen on the one side and the sparrow's life on the other a comparatively easy one. This, however, does not fully account for the wonderful increase of the sparrow kind in the Canadian West. The student may suggest some of the qualities which have enabled this bird to thrive in a country so different from his English home.

Migration.—As the short autumn days come on and food grows scarce, many of our birds migrate to the south, a few only remaining to brave the cold and possibly the famine of the winter-season. This annual migration of the birds is a fact well known to every person. What is its explanation? Why do the birds go south is easily answered. Why should such birds return? Poets have sung and philosophers have discussed this remarkable phenomenon, but it stands to-day practically unsolved. The latest attempt at an explanation connects the coming and going of the birds with the amount of daylight a region may have at any particular season of the year. Birds are voracious feeders. From early dawn to the last minute of daylight birds are searching, searching,

searching for food. As the autumn season approaches with its short days and its long nights, sufficient food for the needs of the birds can not be collected; hence the migration to the south. Similarly in the spring, the birds leave the south, where the daylight is shorter than it is in the temperate and arctic belts of the north. This is the substance of the latest theory. It is not entirely satisfactory, but it may form a theme about which a good class-discussion may take place.

Courtship.—With the birds, as with human beings, there comes a time when the idea that it is not good to live alone, takes possession, and all the energies become centred upon the finding of a mate and the commencement of a home. The season of courtship among the birds occurs in the spring after the return from the south, and is accompanied by various antics, music, colors, etc. In the barnyard, the male birds will give battle to each other and the mightiest will lead the flock. Among many of the other birds, each female seems to have the right to choose her mate, and this mating is sometimes a life-long tie, broken only by the death of one of the twain. How is this selection made? Possibly on the ground of song, for birds seem to exert themselves at this season in the matter of music. Possibly on account of the strange antics of the male as instanced in the turkey-gobbler, the crane and the cowbird. Beauty of plumage may also be an attraction. A savage sticks feathers in his hair and thinks himself beautiful. Surely feathers should play their part most in the animals to whom they rightly belong. No number of examples from a book can equal an intelligent observation on the part of the student. Study birds in the spring season yourself.

You will find that a love for such a thing will grow upon you, and such a possession may not be a bad asset to take with you throughout the remainder of your life.

Nest Building.—After the mating comes the nest building, a work the rooster ignores, and a work too that the hen is no artist in performing. The sparrow's nest is a little better, but it is far from being artistic. The form which the nest may take, and its situation vary very much, though constant in the case of any particular bird. Make a study of the nests of the crow, robin and oriole or hangbird with the view of becoming acquainted with variety in bird architecture and the means used in concealing the nest from strange animals.

Egg Laying.—In egg laying such birds as the domestic hen and the prairie chicken lay many eggs, while the sparrow and many other birds lay but a few. Has this any explanation? Is it true that birds lay many or few eggs in indirect proportion to the character of their enemies? In other words, the nest of the prairie chicken, Fig. 36, is on the ground. Above it are the

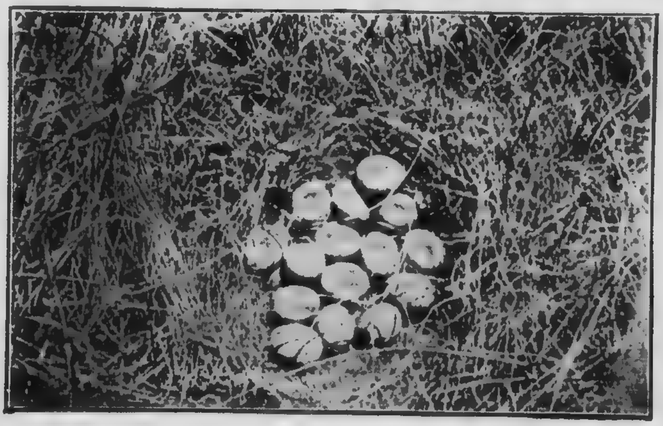


FIG. 36.—Nest of Prairie Chicken.

many birds of prey that would feed upon its eggs and young if a chance were offered. On the ground are a number of animals that would also molest the nest. The bird itself is a food-bird of man, and the life of the prairie chicken on the whole is a most precarious one at best. May this not explain why the nest of this bird is usually well filled with eggs?

Incubation.—Birds begin life in an egg, but what is an egg? How long does a hen's egg take to hatch? How long does a brooding sparrow remain on her eggs before they are hatched? What makes a hen stay hour after hour on such a homely thing as a dozen of eggs? Does a setting hen keep turning her eggs? How does the chicken get out of the egg? How does the chicken get air enough while in the egg? Describe an incubator. Describe the several parts of a hen's egg, and point out the purpose of each.

Motherhood.—When we come finally to consider a bird's care of its offspring we are considering one of the most beautiful features the world has to show. Birds, as a rule, are ideal mothers. Even the pugnacious sparrow can not be condemned in this matter. It is, however, to the domestic hen we must go for a study of all the nice little signs of motherhood. Listen to her crooning song as the chickens nestle under her wings. See how she leads her flock in search of food. How carefully she steps. Hear her warning call as the hawk appears. These are but a few examples of the many signs of motherhood on the part of the hen; others may easily be added by the student.

There is no bird whose life-story can be so readily studied as that of the hen. Much that is true of the hen is true of every other bird. To be intimate with the birds, even if we do not know very much about them, has the same effect upon us as an intimacy with the flowers. To encourage this intimacy, we are going to ask that each student shall gather the following information in connection with at least ten of our commonest wild birds and record the same in the blank pages at the end of this chapter.

Name.	
Arrived.	
Began to nest.	
Location of nest.	
Materials of nest.	
Number of eggs.	
Color, etc.	
Time of incubation.	
Time young remained in nest	
Number of broods.	
Departure in fall.	
Remarks.	

Questions.

1. What work of birds is the most severe on their feathers? 2. Describe the ears of a hen. 3. Why are the bones of a bird so rigidly connected? 4. Bend a hen's toes to find how many bones there are in each. 5. Find the oil gland. 6. How do birds use the oil gland? What is the purpose of the oil? 7. Draw and describe a large feather. 8. Describe the contents of the barrel. 9. Examine the feathers and the bones of a bird, and show the part these play in making the bird more buoyant. 10. What is a pin-feather? 11. Watch the feathers when a bird is angry and when the bird is taking a dust bath. 12. What material is in an egg-shell? 13. Does the egg completely fill the shell? Explain. 14. How can a fresh egg be distinguished without breaking it? 15. Note the round spot on the yolk, where it comes nearest the surface This is the germ spot. 16. Why is a hen's egg so large?

THE CAT.

Signs of Wildness.—Of the animals domesticated by man, none show so many characteristics suggestive of their probable savage ancestry as the domestic cat. The dog still hides the bones and circles about before lying down; horses still avoid the marshy grounds and career occasionally from side to side of the field; cows stampede; sheep follow a leader; and poultry select the high roosting places. But none revert more easily than the cat to the original life of the race and there are even some persons who go so far as to say that the cat never has been and never can be fully domesticated.

Prejudice in Observation.—In deciding what is and what is not the nature of the cat there are two classes of persons whose testimony must be taken with a good deal of caution. In the first place we have the person who is very fond of the cat. He sees only good in all the cat kind. He points to the pioneer on the western plains, far away from his base of supplies and forced to lay in a stock of oatmeal, flour, rice, bacon, etc., or sufficient provender for several months. In the wild prairie lands lying about his shack are countless thousands of field mice. These invite themselves and the inevitable result follows, unless the settler is fortunate enough to own a cat. So much for the value of the cat in the country, but what of the city? Why should cats be kept in a city? There are mice in the city and cats are the best of mousers. Besides, cats help to ornament the home; a cat on a rug by the fire-place or the stove gives a cozy and comfortable appearance to the room.

What could children do without cats? Would the child's life not miss a very valuable thing were cats not allowed to associate with human beings? These and other reasons may be offered by the cat admirer. The second person whose opinion must be taken with due caution is the cat hater. This person sees nothing good in cats. He even suggests that a ten-cent mouse-trap would be of greater service than a cat, and besides, would not have to be fed. He objects to the night noises of cats and does not hesitate to mention that cats may be the cause of spreading disease in the neighborhood.

Both the cat lover and the cat hater are prejudiced observers or are likely to be so, and as the main purpose of this topic is to encourage the independent observation of the students in connection with an animal familiar in a sense, but strangely unfamiliar when the actual worth of the cat is being considered. In making observations of the cat, therefore, every student, is advised to enter into the matter as free from prejudice as a judge ought to be when trying a most critical case. Do not look upon the one who has found out something unworthy in the cat as an enemy. Test the evidence upon which the conclusion was based, and if it is found worthy, accept it. This is the attitude of mind science-work should encourage, and it is this very attitude that lies at the foundation of all true science teaching and science study.

Local Instinct.—Cats seem more strongly attached to the locality than to the individual. The family may leave the old home, but the cat usually remains unless forcibly carried away; even then she may return, and she has often been known to return to the old hunting ground. What is found true of her cousin, the wild cat, is found to hold good in the case of the domestic cat. Again, the cat delights in a still hunt, and resents any assistance on the part of another by moving away. With such a strong attachment to locality it is not strange that cats should occasionally frequent the wilder portions of the farm, make these their permanent hunting ground and practically return again to the wild life.

Domestication of the Cat.—What do you suppose was the occasion of the original domestication of the cat? May it not have been a move on the part of the cat herself? Cats would naturally take up their hunting along the wooded borders of the small meadow and arable lands of the earlier farming classes. A visit now and again to the rude homes of the people in search of its lawful prey could be easily done, and man, molested by the mice, would in all probability encourage such advances until the cat became an additional member of the family and the occupant of the cosiest corner that the hut could afford. In some such manner, we have no doubt, the cat was originally domesticated, and she has been with us ever since, no matter how far we have taken her away from her native wilds.

The cat has been in our homes; seen every day; fed often irregularly, and fondled or abused as the case may be. Have we ever taken time to make a real study of the cat's place in the economy of nature? Why is the cat an occupant of so many homes? Is it because of her fine mousing gifts? Is it because the house would not feel right without her presence? Is there any good reason why she is there, or has she come no one knows why? Is the cat really necessary about the house? It is true that the mice seek the retreat afforded by the house as the winter approaches. It is also true that the walls and floors are often tunnelled by these rodents. It is likewise true that a mousey smell and the suggestion of mice eating and running over our food are not pleasant. All these and more may be absolutely true, and if true, certainly very annoying, but do these difficulties make the cat a necessity? Many answer, "Yes." An equal number say, "No." How are we going to decide the matter? There is just one way of doing this, namely, by making an earnest attempt to study the cat, for, be assured, she has never been properly studied by the majority of those who have sheltered her in their homes.

Feeding. – Beginning then with food and food getting, what do we know regarding the cat? We know that cats drink milk, eat bread, meat, mice and birds. We have even seen cats eating grass or some other form of vegetation. All these we know in a general way, but do we know how many mice and birds the average cat destroys in the course of a year? Here is where our work with the cat should really begin, for on her food habits will depend to a very great extent her value to man as a whole. Mice and birds are not food stuffs furnished by her master or mistress. They belong to her own hunting, and it is her success in this line that has given her the place she now apparently occupies. Has she justified this place? How much care has the cat received at our hands? We have spent hours, it may be, fitting our dog for the hunt, etc.; how much have we done toward training the cat? Has this training, or rather want of training not been either too much fondling or too much of the opposite? Why should one expect a properly behaved cat to grow up under such conditions?

Cats and Birds.—Now no one objects to the cat as a mouser. Nature seems to require cats, hawks, owls and many other creatures, to keep mice in check. It is also no crime for a cat to go bird hunting. Birds are the cats' *natural* prey. But when man assumes the responsibility of keeping a cat, he ought not to abuse that responsibility by allowing the cat to interfere in a field that is of tremendous service to the whole race. "Cats," says Shaler, "are the worst enemies of our common birds. It is estimated that a cat on an average kills *fifty songbirds a year*, to say nothing of the nestlings destroyed during the same time. The state would fine men discovered killing certain insectivorous birds. How absurd to fine a man for killing one bird and at the same time allow him to keep a cat that kills fifty!" To those who know nothing of the value of songbirds, largely insectivorous, this statement may not seem in any way astounding. What is a fair value of such a bird for one season? Those who have made a study of this problem, have placed this value at fifty dollars. Fifty birds at fifty dollars each would net to the country at this rate, just twenty-five hundred dollars. This is a large sum, in fact, so large that many may be inclined to dispute it. Those who know what cats do and what birds do are the only persons whose evidence would be considered for one minute by any competent court. Is the average too high? We think not, for we have seen one cat collect eight such birds in the course of a few hours' hunting. True, the conditions were favorable to the cat. The weather was damp and the birds' wings wet, so that advantage could not be taken of nature's means of escape. Besides, the cat had a family of three or four fairly large kittens. Should you doubt this average the field is open to you, and this matter is of too serious a nature to be settled by any class-room discussion.

Are there not compensations? Do cats not destroy mice? Here we are on favorable ground again for the cat. It is, therefore, the business of students to collect here and elsewhere all the evidence possible as to the mice and birds caught in the course of a single season by individual cats. "Birds are growing fewer and fewer each year," is a warning given on the authority of the government of the United States, where a really systematic attempt has been made to come to some definite conclusion regarding the worth of our native birds. It will not do, therefore, for Canadians to fold their arms while mother cats are at work hunting birds and bird's nestlings for hungry kittens. We have no desire to wage war on the cat. Cats as pets, and as interesting and even valuable members of the household, must never be unjustly treated. We know something of the immense value of taking care of some living thing. But special attention must be drawn to an animal that, by all reliable accounts, is doing much to rid our fields and bluffs of their bird-life; a loss we cannot afford. It is surely not too much to expect that every person of ordinary intelligence should become so acquainted with the food-habits of the average cat that an effort may be made, or a sentiment aroused, that may help to adjust cats and birds better in the future. Such a sentiment in favor of the really valuable birds of our country should soon force all lovers of the domestic cat to see to it that puss must not be allowed to wander abroad where nests and nestlings would be a temptation. Such a sentiment, too, would compel all who wish to keep cats about the place to see that these were properly trained and regularly fed.

Hunting.—While the question just considered is of prime importance, there is nothing in its nature that will interfere with any adequate study of the cat as a whole. It is only when such a study is made that the cat as a machine for the destruction of mice and of birds is really appreciated. What an elastic body a cat has. What a small hole in the fence puss can get through. Once the head passes the obstacle, the body will surely follow. Has the cat any means of determining what openings are and what are not safe for her to attempt? Observe the cat's movements. How quietly she goes about. Every motion points to her chief specialty—hunting. Watch her stalking a bird. How carefully she moves forward until near enough to make the spring effectual. What an amount of muscular energy is thrown into the final movement! It would be interesting here to try to discover just how the cat's body, in other words the cat's muscles, bones, etc., favor the making of such a spring.

Watch puss again at the opening of some runway. How patiently she waits: not a move, not a sound does she make. Any animal possessing such qualities has certainly very valuable means of securing its prey. Look, again, how the cat can climb. No tree is too smooth nor too large for her sharp claws. The nestlings she may not secure must be housed at the very ends of the smallest branches. How well nature has provided her with instruments for securing her prey: good eyesight, keen hearing, stealthy tread, and a wonderfully elastic and muscular body. Cat's paws are to the cat what human hands are to a human being. With her sharp claws she seizes the mouse or bird, and with her sharp teeth she completes the work. Examine a cat's foot carefully. Count the pads, fingers and toes. How does the cat extend and retract her claws? Look now at the cat's teeth and compare them with your own. Can you see any evidences of such teeth being better suited to cutting and tearing than to chewing? Do the cat's teeth suggest much mastication before swallowing? Notice the gape and endeavor to explain its adaptability. Examine the upper surface of the tongue and explain why a cat can clean a bone so much better than a dog can. Look at the eyes and try to find out how they are adapted to night-hunting. Examine the pupil in the day time and also again in the evening. What difference is noted and what does this difference signify? Observe the time of the day when the cat sleeps and when she is most alert. Try to discover all the points favorable to night-hunting. The stray light enables her to make out the positions of sleeping birds. Satisfy yourself as to the value of the cat's whiskers. Is it true that these appendages serve as a measure of the size of the opening the cat can safely get through? Have you ever come across a cat stuck in a fence? Have you seen other animals less fortunate in this particular? Touch the ends of a cat's whiskers to see how sensitive they are.

Find the positions of the cat's knee, heel, and elbow. What gain is made by walking upon the toes instead of upon the whole foot? Does the cat ever place the whole foot upon the floor? When? Make the cat jump from the table so that you may know how this is done. Notice how cleverly she lights on her feet. Trail a string along the floor to see her manner of following and seizing her prey. Do you see any advantage arising from the fondness of kittens for moving objects? Cats are well prepared to take care of themselves. What is the meaning of the arching of the back, the erection of the fur, the movement of the tail, the scratching and the various cat noises? Watch two cats fighting if you would see the best use made of all these weapons.

Devotion or Selfishness.—As the cat is considered one of the best of the dumb mothers, it would be well to make some study of the various signs of affection on the part of the mother-cat. Notice how she treats her kittens; how she nurses them, trains them, washes them, carries and protects them, etc. Shaler says:—"*The cat is the only animal that has been tolerated, esteemed and, at times, worshipped, without having a single distinctly valuable quality.*" Have you discovered anything in your observation of the cat that would appear to justify so sweeping a condemnation of the cat's social qualities? Shaler goes on to say:—"The cat is, in a certain indifferent way, sympathetic, and by her caresses, appears to indicate affection, and has thus awakened a measure of sympathy which she hardly deserves. I have been unable to find any authentic instances which go to show the existence of any real love for her master." Has Shaler seen correctly? It must be borne in mind that a cat's strong attachment to locality may prevent her from showing such affection as a dog shows. The selfish spirit or law of life-preservation shows itself even in kittens a few weeks old. Why should a kitten snarl when given a bit of meat? Does a young dog show this selfish spirit to the same extent? The cat's temper has also been looked upon as uncertain, and the pleasant sound of purring may only mean self-satisfaction or a sign that something is wanted. Do cats leave their food to go for a romp with one? Will the dog? Will the cat make any sacrifice for her master as the dog has repeatedly been known to make?

Cats and Disease. – Finally bear in mind that cats have been the inmates of our homes since long before the dawn of history. How far they are immune from the diseases of children is an open question. A cat that is well will receive much care; a sick cat is bound to get much more attention. Cats as scavengers are not easily controlled. A wound from a cat may not always prove a simple thing. Cats have often been seen gracing the window of a grocery store. Think of what this may mean. Rats and mice must be kept in bounds, but surely by other means than by a house cat living in a home with children. A well-fed cat is a poor mouser, while a cat kept on short rations will go to all sorts of places and come into touch with all sorts of infection. Such a cat, to say the least, is a very questionable companion for young children. The purpose, however, of this chapter is not so much to tell the story of the cat's life, what little we know of it, as to point out the way the story may be read in living nature about us. If this story is to be filled out and the bounds of human knowledge widened, it will be due to the faithful observations of the students, whose interest we have succeeded in arousing.

Questions.

1. Describe the fur of the cat. 2. Compare the sole of the cat's foot with that of the dog. 3. How many claws has each foot, and how do the claws differ from a dog's claws? 4. How does a cat climb a tree? How get down? 5. Point out all the qualities that assist the cat in combating her enemies. 6. Write a short account of the cat's relations to the birds. 7. Does the cat show real affection for her mistress or master? Point out any features for or against this. 8. Make observations on—the cat a weather-signal; the cat's hatred of the wet; the cat and the pantry; the cat and the barnyard.

ELEMENTARY ASTRONOMY.

Earth and Sky.—In the childhood of the race, men saw the earth as a flat surface stretching away in every direction to a circular boundary called the *horizon*. Above, they saw the heavens like a dome, with its edges resting on the horizon. Every day they saw the sun rise above the horizon's edge on one side, pass over the dome of the sky, and sink to rest below the edge of the horizon on the other side. At night they saw the moon take the same course, and at night too they saw the sky studded with a myriad of stars. All these the children of the ancient past saw, and some of their wisest pondered over what was seen and tried to explain it.

To-day we are in danger of forgetting that the "heavens declare the glory of God." We look too much earthward, and we miss the magnificent picture of the heavens and the opportunity of discovering a few of the greatest facts that modern geography has to teach. How many persons have actually worked out such problems as:—Does the earth really turn on its axis? Has the moon a motion on its axis? How do we know that the earth revolves about the sun? These and a score of other just as interesting problems have been taken on faith, and no desire has been created to get at the meaning of some of the things that have practically created a new heavens and a new earth to human beings. To arouse some independent thought, to cause students to take a more intelligent interest in a few of the notable things of astronomy, and to encourage all, rich and poor, old and young, in an attempt to think the thoughts of some of the world's greatest masters over again after them, are among the purposes of this chapter.

The New Moon.—In the western sky shortly after sunset, a crescent-shaped moon may be seen at regular intervals. To get acquainted with the *new moon*, as this phase is called, is to look forward ever after to the appearance of this moon. An object that has proved a source of much interest to people in all ages of the world's history can surely not be devoid of interest to modern men and women. What can be seen in this wonderful phase of the moon? How we should gaze at it were it to appear but once in a century! Let us notice its exact position from time to time. How far above the horizon is it when first seen? How long after sunset does it disappear below the horizon? What is the color of the crescent? Which way do the horns point? Do they always point in this direction? From time immemorial, people have seen these changes in the position of the new moon and have attached thereto much weather-wise lore. When the horns point earthward, it is a sign of wet weather. When the moon stands well to the south, fair weather must surely follow? Are these signs to be depended upon? Many very excellent people rely upon them, and to question the moon-lore of some of these people is to gain their displeasure. What is the right attitude to take in such cases? Has not each student a fair chance to come to his own conclusions regarding the influence of the moon upon the weather? Why not make a record of the phases of the moon and the character of the resulting weather for this year? Have you seen the "old moon in the arms of the new"? Have you discovered any reason for this? Were you standing on the dark portion of the new moon and looking toward the earth, what do you think you would see? You would see the earth shining like a very large moon, for the earth is very much larger than the moon, and therefore receives much more sunlight than the moon receives. This sunlight is in part reflected towards the moon, a fact that may assist you in solving the "dark of the moon" mentioned above. How do we know that the earth light may be the cause of this appearance? The new moon is visible just a little after sunset is it not? The moon and the sun must have crossed the sky from east to west at practically the same time? The sun would light up half the earth and the greater part of that half would be facing the moon. In other words, a study of this position of the sun, the moon, and the earth, means that when the moon is entering the phase called the new moon, the earth is leaving a phase, we should call, were we living on the moon, "*full earth.*" When the earth-light is full, the moon is not visible, and when the moon is full, the earth is not visible; the light of the earth and the moon are therefore complementary.

Returning to the cause of the "dark ball," we find that the earth-light falling upon the moon's surface comes from nearly the whole face of the earth. As the earth is many times the size of the moon this light must be much greater in intensity than the moonlight from the full moon could be. This earth-light illuminates that portion of the moon's face that we think is dark to such an extent that its outline against the sky of the background is plainly seen. After a few evenings, the crescent being larger, and the earth-light diminished, the dark ball fades from the sight. Another factor bringing out the "dark moon" is the very mild light of the crescent. How so? Think of a candle-light at mid-day. In making observations of the character of the new moon it will be well to note accurately the moon's time of setting for at least three evenings. Take the average loss and see what this means in the course of a moon-month.

The First Quarter.—Several days after the first appearance of the new moon, the moon will be half illuminated and will have reached the phase called the *first quarter.* Note the position of this moon in the early evening. When did this moon rise? About what time will it set? Is the line marking the left edge fairly distinct? How many days are there from new moon to the moon in its first quarter? Refer to the almanac to see how far astray your answer is.

The Full Moon.—The moon steadily grows (*waxes*) until the third phase, or *full moon* is reached. This is usually a delightful moon for the reason that it furnishes those who wish to be abroad at night with a capital light. Aside from this the full moon is interesting. Note how big it appears at the horizon. Can you account for this peculiarity? Have you been able to make out the human face that so many pretend to find in the moon? Does this face look to the right, left or front? Where is the sun when the moon is rising? Do you see why the moon should be full? Does the full moon rise at the same point on the horizon as the sun? In moving up from new moon to full moon, the moon's growing edge showed an uneven appearance. This is what is called a *gibbous* moon.

Last Quarter.—After reaching the full moon phase, the moon begins to decrease or to *wane.* Make a note of the edge you first see diminishing, and ascertain if the order of waning is the same as that of waxing. The moon rises later and later after the full moon stage has been passed. There may, therefore, be some difficulty after a few evenings in seeing the gradual changing. This is easily corrected in the winter months, for the moon may be seen in the early morning, and its time of rising and setting approximately ascertained. The next stage, or *last quarter*, of the moon is the stage equivalent to the moon in its first quarter. The only difference lies in the fact that this moon is the reverse of the waxing moon. The appearance of the moon between the last quarter and the new moon presents many interesting features. The crescent-shape is shown again, the horns pointing to the observer's right. To see this moon one must look in the eastern sky a short time before the sun rises. Look for signs of the "old moon" here again.

After this the moon will not be visible for a few days, and may not be seen until it appears again in the western sky as the new moon. How is this vanishing of the moon explained? Can you see why an eclipse of the sun should take place between the last quarter and the new moon? Can you also see why an eclipse of the moon should take place about the time of the full moon? Can you likewise see why the moon always presents the same face to the earth? What evidence have you that the moon revolves about the earth? In what time is this done?

The Sun.—There are a few features connected with the movement of the sun across the sky that are easily observed and that tend to make the study of astronomical geography much more interesting. On September the twenty-second; in other words, at the time of the autumnal equinox, make a note of the exact points where the sun rises and sets. Note the curve taken in the sky between these points. About what part of the whole circle is this curve?

Take the altitude of the sun at sun-noon. To carry this out, set a stick (a piece of a broom-handle with a sharp nail in one end will do) vertically on the floor in the sunlight. Between ten and eleven o'clock, note the end of the shadow cast by the stick and mark this with a piece of chalk. Make a loop at the end of a cord and drop this loop over the vertical stick. With the stick as centre and the length of the shadow as radius describe a circle. In the afternoon watch for the presence of the tip of the shadow of the stick on the circle. Mark the exact spot and bisect the curve between the two marks. Produce this line of bisection in the direction of th stick. This line is the noon-line of the sun. Whenever, therefore, the shadow of the stick falls upon this line the sun is on your meridian. Compare sun time and school time. What direction does the noon-shadow take? Where are the real east and west? Now construct a right-angled triangle having the vertical arm the exact length of the stick, and the horizontal arm the exact length of the noon-shadow of the stick. Join the ends of the arms and ascertain the angle made by the hypothenuse and the horizontal arm. This angle gives you the altitude of the sun at noon, September 22nd.

Make a note of the points of the sun's rising and setting and also the length of the day at least once every two weeks. What have you learned from this? May we say that as the sun rises more and more to the south and sets more and more to the south, winter is coming nearer and nearer? On December 21st make the same kind of observations that were made on September 22nd. This is what is called the mid-winter sun, and the sun's altitude at this time is the least possible for our latitude and the daylight necessarily the shortest of the year. Take the difference of the December and September altitudes and note the angle of difference. How does the angle compare with the angle representing the inclination of the earth's axis? How is this explained?

The Stars.—In January you will see between the eastern horizon and the zenith a cluster of stars like that in Fig. 37.

This is the constellation of *Orion*, one of the finest of the many fine constellations. Watch this constellation, say once a week for a period of three months, and note its behavior. Soon its place will be taken up by other constellations coming up from the east, which in turn pass on and disappear towards the west.

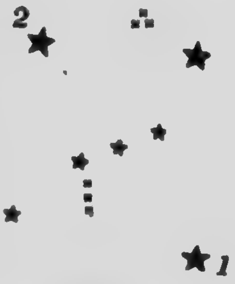


Fig. 37.

The ancient astronomers saw this strange phenomenon and explained it in their own mythical way. What does such a thing signify? Some have put it this way (Fig. 38):—

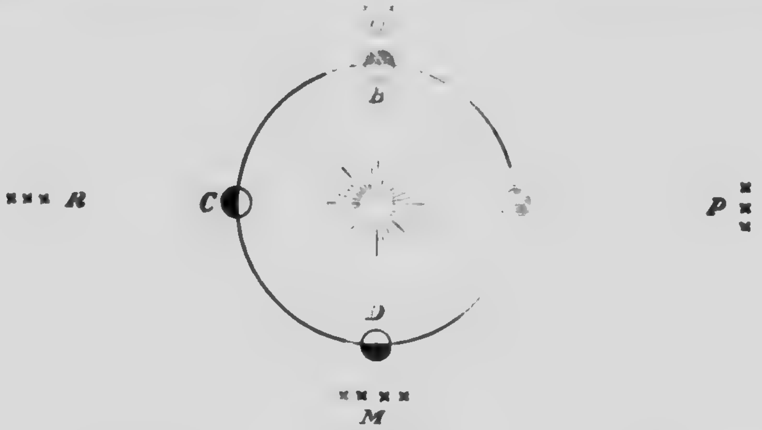


FIG. 38.

A passenger is travelling round a circular track A, B, C, D. At A, he passes a stone house; at B, he passes a brickyard; at C, a herd of cattle in a field; and at D, a windmill. As the passenger goes by A again he says:—"Why I have seen that house before." This is confirmed at B, and again at C and D. The passenger finally concludes that he has been on a circular track.

In the same figure, A, B, C, D is the orbit of the earth about the sun, A, B, C and D representing stages in the journey, separated by periods of three months. At A, a man we may suppose, views the heavens above his head and sees a cluster of stars designated P. Three months later at B he does the same thing at the same time, but sees a new constellation Q, while the constellation formerly seen above is now disappearing below the western horizon. At C he sees a new constellation R, and at D still another constellation M. Finally he returns to A where he sees again the same constellation of a year ago. He says, or may be supposed to have said:—"Why, I have been here before!" This conclusion is confirmed at B, and reconfirmed at C and D. In other words, the observer and the earth have made a journey about the sun, and the stars have made a record of this journey.

Finally take a good look at the constellation called the "Great Dipper." Count the stars in this constellation, noting their respective positions. The two outer stars point to a large, bright star much higher in the sky. These stars are called the *pointers*, and the star pointed to is called *Polaris*, or the North star. Watch the behavior of the Dipper a few evenings. Find out how it turns about the North star. Does it move in the direction of the hands of a clock or the reverse direction? How high is Polaris? Pick on some star farther away from the North star and note its motion. Follow this until you can satisfy yourself that some stars never set and others rise and set. Finally, take enough interest in the sky to become acquainted with the main planets and constellations.

Questions.

1. What have you observed as to the effect of the moon on the weather? 2. Does the winter-moon ride as high in the sky as the summer-moon? 3. Read the myth in connection with Orion. 4. Find out the meaning of the morning and the evening stars. 5. How far north of the equator does a vertical sun get? Why not farther north than this? 6. If the earth's axis inclined 40° to the plane of the earth's orbit, where would the tropics be placed? How wide would the Torrid Zone be? How wide would the North Temperate Zone be? How would this affect the summer season of the Canadian West? 7. Find out the names of the stars marked 1 and 2 in Fig. 37.

PHYSICAL SCIENCE.

Introduction.—The word "science" is derived from a Latin word which means "to know," and scientific knowledge differs from common knowledge only in being more orderly and exact.

Our senses make us aware of the fact that there are objects outside of ourselves. Such objects we call *matter.* Matter cannot be defined, but is known by its properties. Anything which occupies space, has weight, or offers resistance, may be classed as matter. From this it is evident that such substances as wood, plaster, stones, clay, sand, water, are matter, but what is to be said of air? If we are not certain we may arrive at a satisfactory conclusion by making a test.

Experiment 1.—Press a tumbler mouth downward into water (Fig. 39). Does the water fill the tumbler? Why? Is air matter? Why?

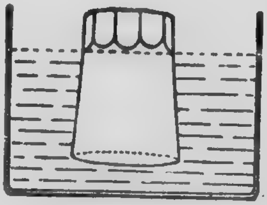


Fig. 39.

Such a test as the above made *for the purpose of gaining knowledge* is called an *experiment.* Before performing an experiment the student should know what information he is aiming to gain by the test he is making. Without a definite aim he is simply toying with apparatus and is not experimenting in any sense.

THE ATMOSPHERE.

Does air press on the objects it surrounds?

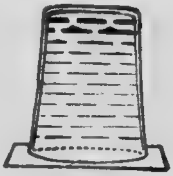


FIG. 40.

EXPERIMENT 2.—Fill a tumbler with water. Cover the top with a piece of paper. Hold the paper in place and invert the tumbler as in Fig. 40. Remove the hand. Does the water run out? Why?

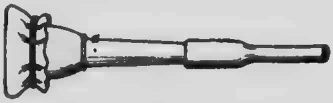


FIG. 41.

EXPERIMENT 3.—Fasten a sheet of thin rubber over the wide end of a funnel or thistle tube as in Fig. 41. Put a piece of rubber tubing on the small end. By placing the mouth at the small end suck out some air. Squeeze the tube to prevent the air from returning. What form does the rubber on the large end take? Why? Turn the end of the funnel upwards, downwards, sidewise. Does the air press in all directions? Did the air exert pressure on the end of the funnel before the air was drawn out? Why was the sheet rubber not bent? Suggest a reason why we are not more conscious of the pressure of the atmosphere. How was it possible for you to take part of the air from the funnel by suction? How do we take air into the lungs? How is it expelled from the lungs?

EXPERIMENT 4.—If your laboratory is supplied with an air pump, place a bell jar on the plate of the pump and extract part of the air. Try to lift the jar from the plate. Account for the result.

Make a statement of what you have learned from Experiments 2, 3 and 4 with regard to the pressure of the atmosphere.

Is air compressible?

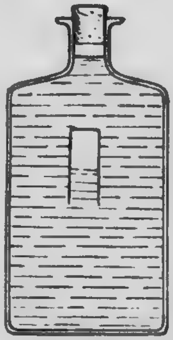


FIG. 42.

EXPERIMENT 5.—Put enough water into a small thin glass bottle or test tube so that it will *just* float when inverted in water. Place it in a larger bottle of water as in Fig. 42. Now press a rubber stopper into the large bottle and observe the air in the small bottle. Does its volume change? Why? Is air compressible? Why does the small bottle sink?

NOTE.—If the large bottle is flat and the stopper carefully adjusted, the small bottle may be made to sink or rise at will by squeezing the large bottle

When the captain of a submarine boat wishes it to sink beneath the surface of the water he opens a valve which allows gas to escape from a chamber and water to take its place. To bring the boat to the surface the water is again replaced by gas. Why is it possible to pump air into a football which is already full of air? Explain the working of the bellows.

EXPERIMENT 6.—Fill a test tube with water. Place the thumb over the open end, invert it and place the mouth just under the surface of water. Remove the thumb. Why does the water not run out of the tube? If the tube were 35 feet long the water would fall two or three feet when the thumb was removed. Account for this fact. Mercury is 13.6 times heavier than water.

If the atmosphere will support a column of water 33 feet high, what is the height of the mercury column which it would support? If your laboratory is supplied with a barometer tube, fill it with mercury, invert it in a dish of mercury, measure the height of the column and find if your calculation is correct. (If 33 feet were correct for your altitude the mercury column should measure 29.1 inches).

The pressure of the atmosphere is less before rainy or windy weather, hence at such times the column of mercury is not so high as in fine weather; thus the barometer is a useful instrument to foretell the weather. It will also be seen that the barometer may be used to measure the height of mountains since the atmospheric pressure must decrease as we ascend, leaving part of the atmosphere below us. Near sea level the barometer falls about 1 inch for an ascent of 900 feet.

The average barometer reading at Brandon is 28.8 inches, while at sea level it is 30 inches. What is the height of Brandon above sea level?

We live at the bottom of an ocean of air 200 miles deep though one-half of it lies within 3½ miles of the earth's surface. The atmosphere presses about one ton on every square foot of surface, hence our bodies are subjected to an enormous pressure. We suffer no inconvenience from this since air and other gases within the tissues of the body counterbalance this pressure. If, however, we were to ascend to great heights, as in mountain climbing, the outside pressure would be lessened and the pressure from within the tissues of the body would probably drive blood out through the thin membranes of the nose or ears. Mountain climbers often suffer in this way.

The Common Pump.—The atmospheric pressure is an important factor in the working of liquid pumps, as will be seen by the study of the common pump. When the piston (Fig. 43) is pushed down the valve at *b* closes and the air raises the valve *a* and rises above it. On the upward stroke *a* closes, and the air above it is lifted, decreasing the pressure below the piston. The air below *b* now raises the valve *b* and flows into the space below the piston. The air pressing on the water of the well at *c* forces the water up the pump. When the piston again descends valve *b* closes as before and the water raises the valve *a* and flows above it to be lifted on the upward stroke to the spout where it runs out.

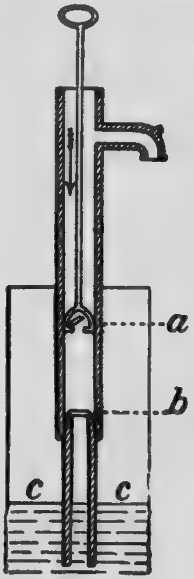


FIG. 43.

Draw a diagram of the pump showing the position of the valves in the upward stroke of the piston.

Since the atmospheric pressure is equal to the weight of a column of water not more than 33 feet high, what is the greatest height that the piston may be placed above the level of the water in the well to allow the pump to work? How high could mercury be drawn? Explain the necessity of long piston rods where water is pumped from deep wells.

From the study of the pump explain the drinking of water through a glass tube or straw. Why can this be done without the use of a valve?

Questions.

1. Define science, matter, experiment. 2. How would you show that air presses equally in all directions at a given point? 3. What properties of air make it useful for filling bicycle tires and footballs? 4. How does a captain of a submarine cause his boat to sink below the surface? 5. Why is mercury used in preference to water in the construction of a barometer? 6. For what purposes may a barometer be used? 7. What is the weight of the atmosphere on an acre of ground when the barometer reading is 29 inches? 8. The altitude of Winnipeg above sea-level is about 700 feet, what should be the average reading of the barometer at Winnipeg? 9. Twelve cubic feet of air weigh about 1 lb., find the weight of the air in your schoolroom. 10. Why should a person breathe faster on a mountain than in a valley? 11. Measure the length and width of your hand and estimate the pressure of the atmosphere on it when the barometric reading is 28 inches. (Note.—A cubic foot of water weighs 62½ lbs. and mercury is 13.6 times heavier than water.) Why is your hand not crushed by such a pressure? 12. Why do mountain climbers often suffer from bleeding at the nose? 13. Why should a pump with a large piston be difficult to work? 14. Make a diagram to scale of a pump to raise water from a 50 foot well. 15. What is wrong in a pump which has to be primed before it will draw water? 16. To keep a pump from freezing, a small hole is bored in it to allow the water to run off. Would it matter whether this hole were bored above or below the cylinder in which the piston works? Explain. 17. Although it is possible to draw water over 30 feet, in practice pumpmakers place the cylinder as near the water level of the well as possible. Show the wisdom of this.

MACHINES.

Force, Work and Power.—A *force* is that which causes or tends to cause motion. If a boy pushes or pulls on a hand-sleigh, he exerts force even though he is not able to move it. When a force acting on an object causes it to move, *work* is said to be done. If the boy causes the sleigh to move he does work. The amount of work he does depends on the measure of the force he exerts and on the distance through which the force acts. If he pulls ten pounds on the sleigh and continues with the same force until the sleigh moves one foot he does *ten foot pounds* of work. To lift a 100 lb. sack of flour vertically through two feet would require 200 foot pounds of work.

The rate at which work is done is called *power*. The unit of power in common use is the *horse-power*. It is estimated that the average horse can pull with a force of 100 pounds and walk at the rate of 3¾ miles per hour, or in other words, he can work at the rate of 33,000 foot pounds per minute. Machinists use this standard when they speak of an engine as being of 10 horse-power, etc.

Machines.—In order to apply force to good advantage, man uses devices which are called machines. A machine cannot of itself do work, in fact work is lost in a machine for it requires force to move it. Nevertheless the advantage often more than makes up for the loss. The advantages gained by machines are:—

1.—Force may be applied in a more convenient direction. For example, a workman may stand on the ground and raise a bunch of shingles to the roof of a building by means of a rope and pulley. The man pulls *down*, the shingles move *up*. What other advantage is gained?

2.—We may use other forces than our own to do useful work. Horses, the wind, steam, water or electricity may thus be made to do our work for us.

3.—A great force moving slowly may be used to make a small body move rapidly, or a small force moving rapidly may be made to move a large body slowly.

The third use is one of much importance, and in the description of a few simple machines which follows, the student should note carefully the relations between the forces and the distances through which they move.

The Pulley.

EXPERIMENT 7.—Arrange two pulleys as in Fig. 44. The counterpoise *c* should be heavy enough to support the weight of the lower pulley. Make *w* any convenient weight and make *f* heavy enough to support it. Compare the weights of *f* and *w*. Pull *f* down a distance of two inches and measure the distance *w* moves. Repeat, using different distances.

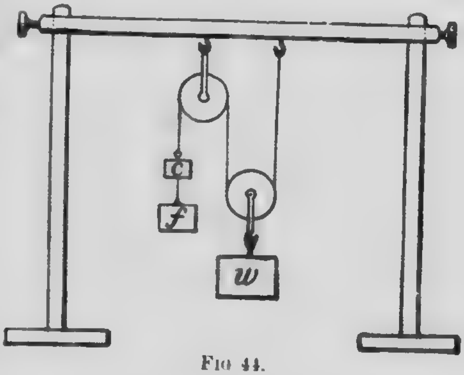


FIG 44.

NOTE.—If pulleys cannot be secured, a hard string sliding through smooth iron rings will answer fairly well. Small spring balances may be used instead of weights *w* and *f*.

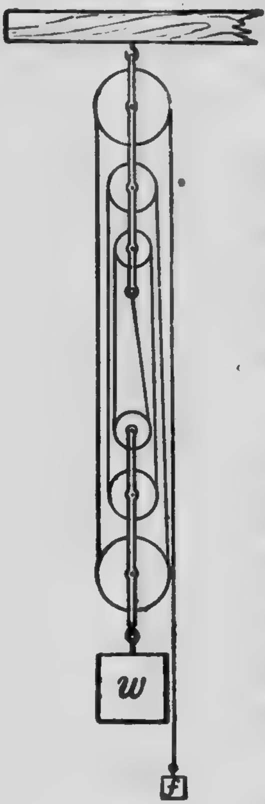


FIG. 45.

What are the two advantages gained by pulleys arranged as in Fig. 44? With such a system what would be the heaviest weight a man weighing 150 lbs. could raise? Through what distance would *f* move to raise *w* five feet?

A number of pulleys are often arranged as in Fig. 45, so that a great weight may be raised by the use of a moderate force. If a man weighing 150 lbs. were to use all his weight in pulling at *f*, how many pounds could he raise at *w*? How many feet would *f* move in order to raise *w* two feet

NOTE.—It will be seen that 1 lb. at *f* will raise 6 lbs. at *w*. Give reasons for the correctness of this answer.

The Lever.

EXPERIMENT 8.—Take a three-foot rule or any straight bar marked off into fractions of an inch. Arrange this on a pivot *(fulcrum)* as in Fig. 46 Place a counterpoise *c* on the shorter arm to balance the greater weight of the longer arm. Attach spring balances at *P* and *w*.

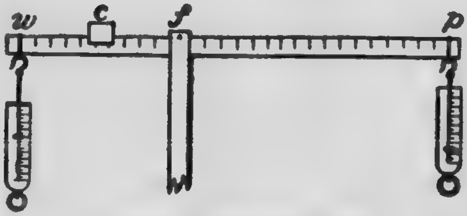


FIG. 46.—First-class Lever.

Pull downward on the balances with forces such that the lever is kept horizontal. Take the readings *P* and *w*. Compare the product *P* × distance *P f* with *w* × distance *w f*. Measure the distance *w* moves while *P* moves a given distance, say four inches. Compare the product *P* × the distance it moves with the product *w* × the distance it moves.

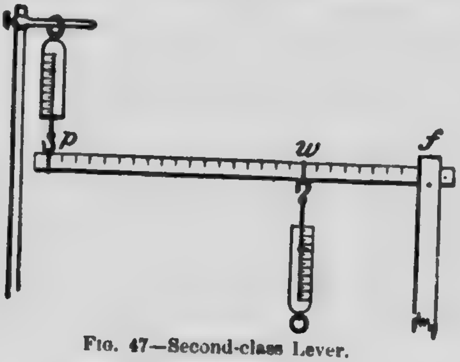


Fig. 47—Second-class Lever.

Experiment 9.—Perform similar experiments with levers of the second and third class, arranging the levers as shown in Figs. 47 and 48.

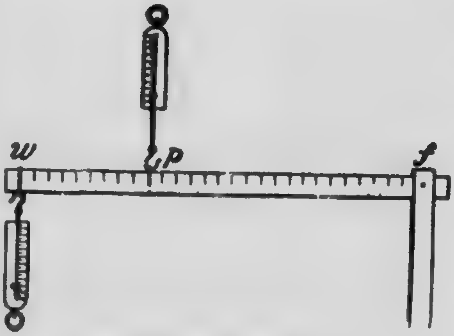


Fig. 48.—Third-class Lever.

Repeat Experiments 8 and 9, varying the distances *p f* and *w f*.

The above results should be expressed as follows:—

The power multiplied by its distance from the fulcrum is equal to the weight multiplied by its distance from the fulcrum, or the power multiplied by the distance through which it acts is equal to the weight multiplied by the distance through which it acts. ***This is called the law of levers.***

The law of levers is the law of all machines, and may be briefly stated thus:—*The force and the resistance vary* INVERSELY *as the distances through which each acts.*

Be sure that you understand the meaning of the word "*inversely,*" for example, the quantity of sugar that may be purchased for one dollar varies *inversely* as the price per lb. Give other examples of its meaning and compare it with the term reciprocal as applied to fractions.

The Wheel and Axle.

In the wheel and axle shown in Fig. 49, the axle is much smaller than the wheel and turns with it. The mechanical advantage gained by this device is explained by the principle of the lever. It is evident that $w \times b\,c = f \times a\,c$.

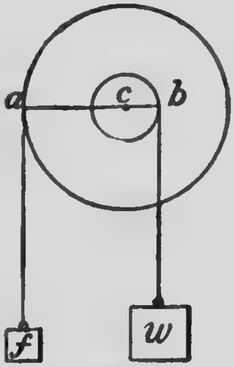


FIG. 49.

Examples of the wheel and axle are found in the windlass and the capstan.

Gear wheels (Fig. 50) are much used in machinery. The principle is that of the wheel and axle. By using a train of geared wheels great mechanical advantage may be gained.

When the diameters of *b* and *c* (Fig. 50) are known and the number of cogs in *a* and *d*, the relative values of *w* and *f* may be found by applying the law of machines.

For example, if the number of cogs in *a* and *d* be 27 and 9 respectively, then *b* will make 3 revolutions for each

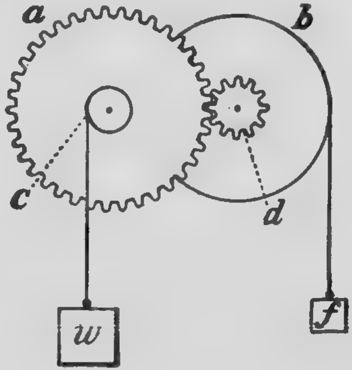


FIG. 50.

revolution made by a. $\therefore f \times 3$ times the diameter of $b = w \times$ the diameter of axle c. What is the principle involved in the gear of a bicycle?

The Inclined Plane is used to enable a small force acting through a longer distance to accomplish the work of a larger force acting through a shorter distance. For example, in Fig. 51 if $b\,c$, $a\,b$ and $a\,c$ represent the distances 3, 4 and 5 ft. respectively, the weight w is raised a vertical height of 3 ft. in moving 5 ft. up the inclined plane. If $w = 100$ lbs., then $3 \times 100 = 5 \times$ force required to move it up the plane, *i.e.*, $f = 60$ lbs.

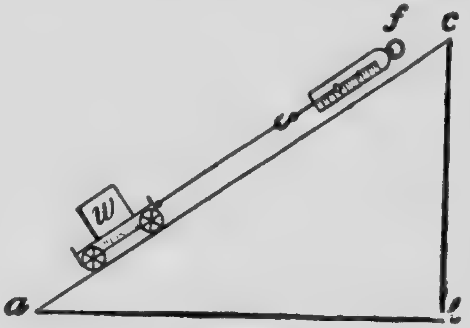


FIG. 51.

The Wedge (Fig. 52) has two inclined faces, and is an example of the application of the principle of the inclined plane. In moving the distance $d\,c$ the block is opened the distance $a\,b$.

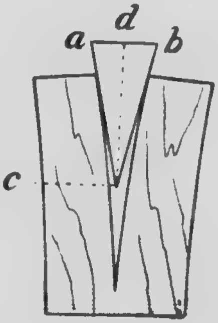


FIG 52.

The Screw (Fig. 53) which is a combination of the inclined plane and the lever, raises the weight a vertical distance equal to the distance between two adjoining threads for each complete revolution of the lever.

If in figure 53 there are 5 threads to the inch on the screw and the lever is $3\frac{1}{2}$ ft. long, then the power will move a distance equal to the circumference of a circle 7 ft. in diameter, while the weight is raised $\frac{1}{5}$ of an inch.

$$\therefore w \times \tfrac{1}{5} = f \times 7 \times 12 \times \tfrac{22}{7}.$$

$$\text{Or } w = 1320 \times f.$$

That is a pull of 1 lb. at f will raise 1320 lbs. at w, if no allowance be made for friction in the screw.

Great mechanical advantage is gained by means of the screw, and hence it is used for raising buildings, lifting large masses of rock, drawing timbers of buildings into place, etc.

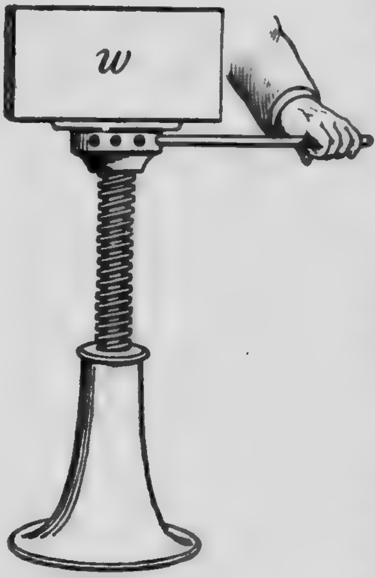


FIG. 53.

NOTE.—Part of the works of an old clock may be used to illustrate the wheel and axle and the gear wheels; a toy cart and a smooth board placed at different angles for the inclined plane; an axe, the blade of a jack-knife or a chisel for the wedge, and a bolt and nut or a vise for the screw.

Questions.

1. Define force. Give examples. 2. Define work. What is a unit of work? 3. A man weighing 180 lbs. in climbing a stairs rises vertically 12 feet. How much work does he do? 4. How much work is done in elevating 100 bushels of wheat a height of 80 feet? 5. How many foot pounds of work is done in pumping 50 gallons of water from a well 40 feet deep? (A gallon of water weighs 10 lbs.). 6. A team of horses draws a load of $1\frac{1}{2}$ tons up a hill 60 feet high. How much work is done 7. Perform 10 foot

pounds of work on a 2 lb. weight. 8. If to pump 2,000 gallons of water from a certain well requires an expenditure of 600,000 foot pounds of energy, find the depth of the well. 9. Define power. What unit of power is in common use? Define this unit. 10. Of what power would the engine in an elevator require to be so that it could elevate 1,800 bushels of wheat a height of 80 feet in an hour? 11. Niagara Falls is 150 feet high and it is estimated that 700,000 tons of water pass over in a minute. If all this water were utilized, what horse-power could be developed? 12. Find the horse-power of a steam engine from the following data:—Inside diameter of cylinder 14 inches, length of stroke 2 feet, number of revolutions of flywheel per minute 100, pressure of steam in boiler 120 lbs. to the square inch. No allowance for waste.

$$\frac{7 \times 7 \times 22 \times 120 \times 4 \times 100}{7 \times 33000} = 224 \text{ H.P.}$$

13. What is a machine? What may a machine do for man? 14. Draw a diagram of a system of pulleys by which a boy weighing 100 lbs. could raise a 300 lb. weight. 15. If in Fig. 54 the distance from the fulcrum *f* to the nail is ½ inch and the distance *p f* is 12 inches, how much force is exerted on the nail by pulling 20 lbs. at *p*? 16. Explain the advantage gained in the handle of a pump. 17. Draw a diagram for a 3-horse doubletree, such that each horse may do ⅓ of the work. 18. In a 4-ft. doubletree attached to the load by its middle point, show how to attach the singletrees that one horse may do ⅓ more work than the other. 19. What class of lever is used when the hand, palm upwards, is raised to the shoulder? 20. (1) State the law of levers, (2) the law of machines. 21. The axle of a windlass is 6 inches in diameter and the crank 2 feet long, find the weight of the bucket which may be raised by exerting a force of 50 pounds on the handle of the crank. 22. Gear wheels are arranged as in Fig. 50. If there are 42 cogs in *a* and 7 cogs in *d*, and the diameter of *c* is 6 inches, while that of *b* is

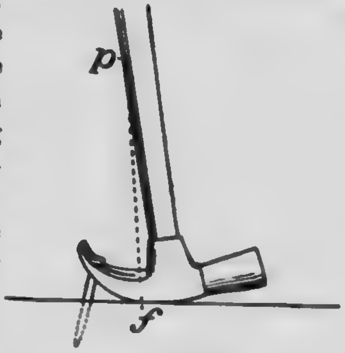


FIG. 54.

24 inches, find the force necessary at *f* to raise a weight of 1 ton at *w*. Answer, 83.3 pounds. 23. A boy who can push with a force of 50 pounds, wishes to raise a barrel of salt weighing 250 pounds into a wagon, a vertical height of 3 feet. Find the length of the shortest plank he can use up which to roll the barrel. 24. If in going up a hill a load of 1 ton is raised vertically 10 feet in moving 100 feet, how much must the horses pull to keep the load moving? 25. If by pulling 20 pounds on a 3-foot lever of a jackscrew a weight of 15 tons is raised, how many threads of the screw are there to the inch. Answer, 6+. 26. State the class of lever and say whether there is a gain of speed or power in the following:—Shears, wheelbarrow, nut cracker, sugar tongs, typewriter, piano keys and hammers, pedal of a sewing machine, piano or organ.

HEAT.

Heat, a Form of Energy.—When a man is active and powerful we say he is full of *energy*. So we may define energy as *the ability to do work*. In the steam engine, water and steam are used simply as media through which heat may be made to cause motion, *i.e.*, to do work, hence heat is a form of energy. There are other forms of energy; for example a moving ball can do work on anything that it happens to strike; an electric current can run a motor. That heat, motion and electricity are all forms of the same thing (energy) seems evident from the fact that one may be changed into the other. Heat in the steam engine produces motion, this motion if transferred to a dynamo appears as an electric current: again this current is changed into heat and light in the electric lamp. Scientists have discovered that *no energy can be destroyed*. Energy may change from one form to another, but the amount of energy in the universe never changes.

Sources of Heat.—If a brass button be rubbed on a piece of soft cloth it soon becomes warm. Where did the heat come from? Similarly a nail hammered on an anvil for a time gets hot. The brakes of a train as it stops at the station become so hot that small particles of the iron fly from the brakes red hot. It will be seen that the source of heat in each of these cases is the *checking of motion;* that is, the energy of bodily motion is changed into the energy of heat.

Heat is also derived from what is known as *chemical action*. For example, when wood or coal burns, one of the gases of the air unites with the substances composing the wood or coal and during this process heat is given off.

The greater part of our heat we receive from the *sun.*

Effects of Heat.—*Change of Volume.*

EXPERIMENT 10.—Place an iron or brass rod 12 in. or 15 in. long, as in Fig. 55, *a* being a lead pencil or glass rod, to the end of which a tooth-pick is fastened by means of sealing wax. Heat the rod. Does the pointer move? Why? If the metal rod represents all solids, how does heat affect them?

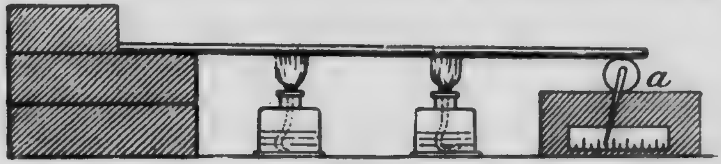


FIG. 55.

EXPERIMENT 11.—Fill a Florence flask with water, push a cork with glass tube through it into the neck so that water may rise into the tube as in Fig. 56. Heat the flask. What is the effect of heat on water? If water be taken as a representative of all liquids, what is the effect of heat on liquids?

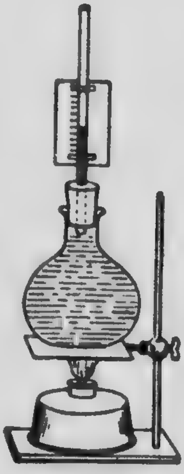


FIG. 56.

The action of the thermometer is due to the fact that liquids expand with heat. The liquid used is either mercury or alcohol. Find out what you can about the construction of a thermometer.

EXPERIMENT 12.—Take a dry Florence flask with cork and tube and invert in water, as in Fig. 57. Heat the flask gently. What comes out of the end of the tube through the water? Why? If air represents gases, how does heat affect gases? Remove the lamp and allow the flask to cool. Does the water rise in the tube? Why? Could the apparatus of Fig. 57 be used to indicate changes of temperature in the room? Such an arrangement is called an air thermometer.

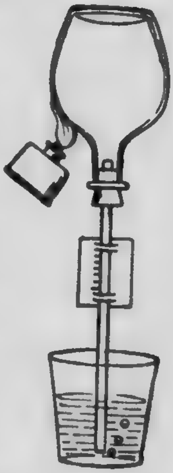


FIG. 57.

From what you have learned in the last three experiments say how heat affects all substances.

How are tires put on wagon wheels and on the wheels of locomotives? Why are the rails of a railway not placed close together? Is any allowance made for expansion in the building of iron bridges? Why do telephone and telegraph wires hum in cold weather? Is there any case in which water expands on cooling? For example, how is a pail affected when it is filled with water and allowed to freeze? Why?

Change of State. Matter may exist in any one of three states, viz:—Solid, liquid or gas.

What change takes place when the following are heated:—Ice, wax, lead, iron and other metals?

EXPERIMENT 13.—Place snow that is beginning to melt in a beaker. Put the bulb of a thermometer into it and take its temperature. Now heat the beaker, stirring the snow until it is just melted. Take the temperature of the water. It should be the same as that of the snow. Since the lamp was giving out heat to the contents the beaker while the snow was melting and no increase of temperature was shown on the thermometer, what became of the heat given out by the lamp? Evidently it was used in changing the solid snow at 32° F. to the liquid (water) at 32° F. Such heat is called *latent.* The heat required to melt a pound of ice would heat a pound of water from 32° F. to 176° F., or from 0° C. to 80° C., hence the latent heat of ice is said to be 144 if the Fahrenheit scale is used, or 80 if estimated by the Centigrade scale. From this suggest a reason for having so much cold weather in March.

Experiment 14.—If you have a thermometer that reads above 212° F., place it in the water of the last experiment and apply heat until the water has boiled for some time. At what temperature did the water boil? After the water began to boil did the thermometer show any further increase of temperature? If not, where was the heat of the lamp going? The heat required to change one pound of water at boiling temperature to steam (a gas) at the same temperature would raise 966 pounds of water through 1° F. or 537 pounds through 1° C. Why does it take so long a time for a kettle on the stove to boil dry? Why is it cooler after a shower of rain in the summer? Why does sprinkling water on the floor cool a room? Why is a person liable to take cold when not careful to change wet clothing? Why does a shower of snow moderate the temperature?

Transference of Heat.—(1) *Conduction.* If one end of an iron poker be placed in the fire the other end soon becomes warm. How does the heat get from one end of the poker to the other? In answer to this, it is believed that the small particles (molecules) of matter are in constant motion, jumping to and fro much the same as a pea in a pill box when the box is shaken. Heat causes each molecule to move faster and to swing through a greater distance. The molecules of iron in the end of the poker in the fire would have their motion increased. These would strike against the adjoining molecules, increasing their motion. This process would go on until the hand was reached. This method of transference of heat is called conduction.

Is heat conducted through all substances at the same rate?

EXPERIMENT 15.—Procure rods of copper, glass, brass and iron of the same size and length. Place one end of each in a flame as in Fig. 58. Let four students hold the other ends and see who can hold his rod for the greatest length of time. How do you account for the result? Do all substances conduct with the same readiness?

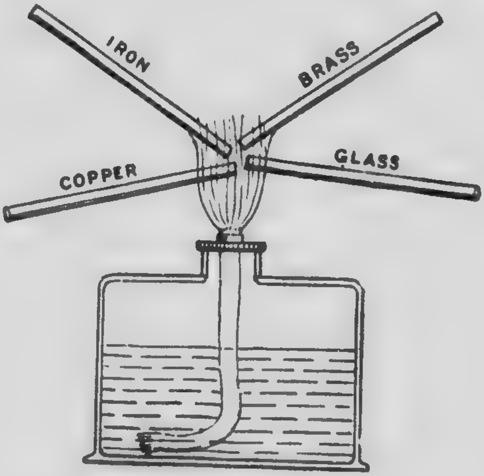


FIG. 58.

Metals conduct heat better than other substances and so they are called good conductors, while wood, glass, wool, snow, air are classed as poor conductors. Why is ice packed in sawdust or straw? Why are woollen clothes warmer than cotton? Why is loosely woven cotton warmer than hard woven cotton?

Are double windows better than panes of glass of double thickness? Why?

Why are air spaces left in walls of buildings? Which is better to bank a house, loose snow or earth? Why?

Why is it that when heating a glass beaker, wire gauze is placed between it and the flame?

Why will a drop of water break a hot lamp glass?

Iron and wood in the room are at the same temperature; why is it that the iron feels colder than the wood?

Why is it that the hands if wet will stick to a piece of iron on a frosty day but they will not stick to wood?

How is it that we are able to breathe air at 40° below zero without injury to the mucous membranes of the nose and throat?

EXPERIMENT 16.—Fill a test tube with water and apply heat to the upper end, as in Fig. 59. Does the

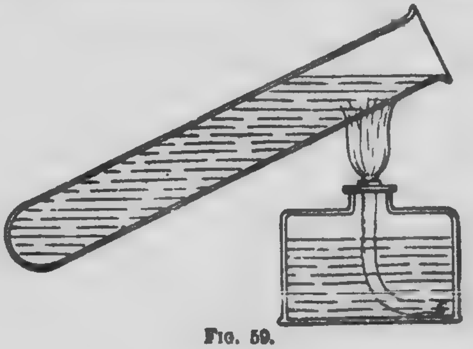


FIG. 59.

water in the lower part of the test tube get hot ? Why ? Is water a good conductor ? Pour the water out and fill again with cold water. Place the bottom of the test tube in the flame and notice whether the water at the top gets hot. Can you account for the difference in the result ? How is water heated ?

(2) *Convection.*

EXPERIMENT 17.—To answer the last question, fill a beaker with water and drop a few grains of potassium permanganate or other solid coloring matter into it and apply heat as in Fig. 60. Any movement of color will indicate motion in the water. How is the water heated ? The heat passes through the glass by conduction. The water on the bottom of the vessel just above the flame is heated. It expands, thus becoming lighter, volume for volume, than the remainder of the water, hence it rises to the surface as a piece of wood would do. The colder water flows in to take its place. It in turn is heated and rises, and this process goes on as long as the heat is applied. *Convection* is the name given this process.

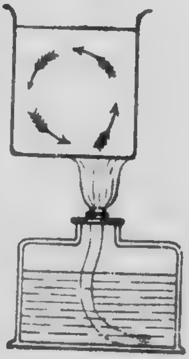


FIG. 60.

Why was the water at the bottom of the test tube in Fig. 59 not heated ? Why is the water at the bottom of lakes and ponds always cold ? The water of the ocean within the tropics is heated only at the surface to a depth of two or three hundred feet, and were it not for the waves and currents it doubtless would be heated for a very much shorter distance.

Are gases heated by convection ?

EXPERIMENT 18.—Cover a wide-mouthed glass jar with a piece of pasteboard in which two holes have been cut. Place a lighted candle under one hole and cover each hole with a lamp chimney as in Fig. 61. Hold a piece of smoking rag or brown paper first over one chimney and then the other, and by watching the smoke, say if the air is moving, and if so in what direction. How is air heated? Use the above experiment to explain the cause of wind. What causes the draught in a stove? Why do many elbows in a stovepipe interfere with the draught? In a building heated by hot air, how is heat transferred from the furnace in the basement to a person in a room upstairs? How can a building be heated by hot water? Why can you always feel a wind when near a great fire? In severe weather the draught of chimneys situated in outside walls is often poor. Explain.

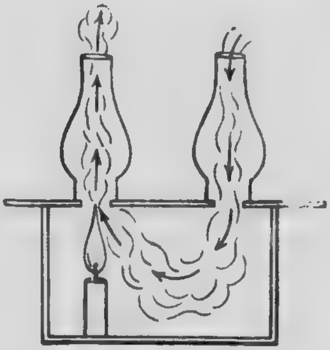


FIG. 61.

(3) *Radiation.* If the hand is held a short distance from the side of a hot stove, heat is felt, but evidently the heat does not reach the hand by either conduction or convection, for as soon as the air between the hand and the stove is heated, it will rise and other air will take its place. Hence there must be a third way by which heat is transferred. It is in this way that heat comes to us from the sun. Heat transmitted in this way without heating the air or other media through which it passes is said to be transmitted by *radiation.* Feel the window-

pane when the sun is shining on it. Does the heat from the sun pass through the glass without heating it?

Radiant heat and light travel at the enormous velocity of 186,400 miles per second. In wireless telegraphy the electric impulses also have this velocity.

EXPERIMENT 19.—Lay a piece of white cloth and a piece of black cloth side by side on the snow in bright sunlight. Examine the snow under them at the end of an hour and find whether the snow is melted more under the one than the other

Rough, black surfaces are good absorbers and good radiators of heat while white surfaces and polished surfaces are poor absorbers and poor radiators. From this you will be able to explain why:—(1) A white hat is cooler for summer wear than black. (2) Tea keeps hot for a long time in a polished silver tea-pot. (3) Summer fallows are hotter than open prairie. (4) Black horses suffer more from the heat than white horses.

In (3) above, grass is a good radiator of heat, but in hot weather large quantities of moisture are constantly being evaporated from the blades and the heat absorbed for this purpose keeps grassy surfaces cooler than bare ground such as summer fallow.

Dew.—Warm air can contain more moisture than cool air. During the day the heated air takes up a great deal of moisture. At night when the sunlight is withdrawn the grass radiates the heat rapidly and becomes quickly cooled. The air in contact with it is cooled so that it is unable to hold all its moisture and part of it is deposited on the cool grass as *dew*. If the temperature is below freezing the moisture is frozen while being deposited and *hoar frost* is the result.

Questions.

1. Define energy. Name two or three forms of energy. 2. State the law of conservation of energy. 3. What change in the form of energy takes place when (1) a piece of iron is hammered on an anvil? (2) an electric lamp is lighted? (3) a bullet strikes an iron target? 4. What are the sources of heat? 5. Outline four experiments to show the effects of heat. 6. Why does warming the neck of a bottle assist in removing a glass stopper? 7. A thick glass tumbler is often broken by boiling water, while there is little danger when the glass is thin. Explain. 8. Why should a loose glove be warmer than a tight one? 9. Water may be boiled in a paper cup. Fold a piece of paper into the form of a square box and try this experiment. Explain why the paper does not burn. 10. A strip of paper rolled around a brass cylinder does not burn when held in the lamp flame. Try the experiment by placing a strip of paper around a brass 50 g. weight if no better cylinder is available. Explain. 11. Why is the climate of islands and countries near large bodies of water less extreme than countries far inland? 12. Why is it necessary to stir thickened milk when heating to keep it from burning to the bottom of the vessel? 13. Why are the walls of houses built with one or more air spaces? 14. To what temperature would a gallon (10 lbs.) of ice cold water be heated by the heat required to change 1 lb. of boiling water to steam? Answer, 53.7° C. 15. Explain fully the manner in which liquids become heated. 16. Outline a method of ventilating a dwelling room, and point out the principle on which your method depends. 17. Why is ice more effective for use in a refrigerator than ice cold water? 18. Ten lbs. of ice are placed in a vessel over a lamp, at the same time 9 lbs. of ice cold water are placed in a vessel over a similar lamp. What will be the temperature of the water when the ice is just melted? Answer, $88\frac{8}{9}$° C. 19. Explain the principle of the tea-cosy. 20. In running stovepipes from the stove to a chimney in the adjoining room, which end of the horizontal section should be higher? Why?

APPENDIX.

Apparatus required to perform the experiments outlined in this book :—

A nest of three small beakers.
One large glass jar (battery jar).
Thistle tube or small funnel.
Three feet of rubber tubing ($\frac{3}{16}$ in. diameter).
Sheet of thin rubber—3 in. square.
Sixteen-ounce bottle (flat).
Small test-tube or pill bottle.
Half dozen test-tubes (3, 4, 5 and 6 inches).
Four small brass pulleys ($\frac{3}{4}$ in. diameter).
Three-foot rule (for lever).
Two spring balances (64 oz.).
One pulley and axle.
Set of gear wheels.
Small wagon.
Vise or bolt and nut.
Three-eighth in. iron rod (round), 15 in. long.
Florence flask (8 oz.).
Two rubber stoppers (solid, $\frac{5}{8}$ in. and $\frac{3}{4}$ in.).
Two rubber stoppers (one hole, $\frac{1}{2}$ in. and $\frac{5}{8}$ in.).
One alcohol lamp.
One pint methylated spirits.
Half-pound soft glass tubing, assorted sizes, $\frac{1}{8}$ in. to $\frac{1}{4}$ in. outside diameter.
Retort stand and two rings.

Thermometer for high temperatures—reading above 212° F.

One brass rod—diameter ¼ in., length 5 in.

One iron rod—diameter ¼ in., length 5 in.

One copper rod—diameter ¼ in., length 5 in.

One glass rod (solid)—diameter ¼ in., length 5 in.

Two lamp chimneys.

Wooden box with one side glass 8 in. × 3 in. × 3 in., 2 holes in top over which to set the lamp chimneys.

Small air pump.

Bell jar.

Barometer tube.

Two pounds of mercury.

Model of common pump (glass).

Set of weights.

Metre stick.

Claw hammer.

Small saw.

A few gimlet bits (gimlet to ½ in. size).

Jack plane.

Small oil stone.

Screw-driver.

Square (small).

Two or three chisels (½ in. to ¾ in. size).

Small combination vise and anvil.

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